O. Craig

# Fuel Conservation in the Buhl, Minnesota Municipal Power Plant

# FUEL CONSERVATION IN THE BUHL, MINNESOTA, MUNICIPAL POWER PLANT

BY

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B. S. University of Illinois, 1909

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THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

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IN

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I HEREBY RECOMMEND THAT THE THESIS PREPARED BY

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ENTITLED "Fuel Conservation in the Buhl, Minnesota, Municipal Power Plant"

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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# FUEL CONSERVATION
# IN
# THE BUHL, MINNESOTA
# MUNICIPAL POWER PLANT.

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## INTRODUCTION

8

In August 1919, the Village of Buhl, Minnesota, requested the Charles L. Pillsbury Co., Consulting Engineers of Minneapolis, Minnesota, to make an investigation of the Buhl municipal power plant and report on what things should be done to secure economy of coal consumption. This work and the subsequent work of monthly inspection was done by the writer as Mechanical Engineer for the Charles L. Pillsbury Co.

It will be recalled that about this time, the United States Fuel Administration was making its most active campaign and this, together with the desire to reduce plant operating expense, led to the request for an investigation by the Buhl authorities.

Buhl is a village in the Mesaba iron mining district of Minnesota. Its population at the time of the 1900 census was about 1000, but it now has a population of about 1500 to 1700. In common with other towns in this district, the village is quite wealthy, receiving tax incomes unknown to towns of such size elsewhere. The tax assessment for the fiscal year 1918-1919, was $233,000.00 and for the fiscal year 1919-1920 was $288,000.00.

In common with other towns in this district, Buhl maintains the municipal form of a village; even Hibbing a town of over 15000 population, has the village form.

Practically all streets in the town are paved with asphalt. The town possesses a village hall built of brick and stone, a beautiful public library built of dark brick, and a large high school building built of dark brick and white stone trim which when present additions are completed, will represent a cost of about $350,000.00.

The main streets of the town are lighted with white way cluster lights and the other streets with arc lights. Water mains are laid in all the streets and water is supplied from a deep well from which it is lifted by compressed air into a concrete reservoir at ground level, and from there into an elevated steel tank by electric motor driven centrifugal pumps. Electric service from the municipal plant is provided to all parts of the town for both light and power.

Steam mains are laid in practically all streets and steam for heating is supplied by the municipal plant to all houses and buildings in the town.

The plant is situated about one block from the business section and sets in a slight depression. The plant is housed in a well constructed brick building having a slate roof.

An investigation was made of the plant the latter half of August 1918, and from the information obtained, a report was compiled which was presented to the Village Board of Trustees. This report is transcribed on pages 10 to 56 inclusively.

Shortly after this report was presented, the Board of Trustees passed a resolution creating a Water, Light, Power, Heat and Building Commission. The creation of such a commission is provided for by law and is optional for municipalities of less than 10 000 population. According to the law under which it was created, this commission had complete control of the municipal power plant, of all outside equipment and its operation, of all plant employees, and of the collection and expenditure of all money in connection with same. The board had all the power of control of a private owner with the added advantage of not being subject to

regulation and of having the power to fix rates.

This commission soon after being formed, made a contract with the Charles L. Pillsbury Co. through the writer, by which the Company was to make monthly inspection of the plant and its operation, receive the monthly records of the plant, and report to the commission on the conditions of the plant and its operation and make such recommendations from time to time as would be deemed advisable.

The purpose of these inspections and reports was to get the recommendations contained in the original report into effect, to bring the plant up to the best efficiency, and to keep the commission informed.

With each monthly report, a curve sheet was furnished showing graphically the variations of operating conditions for the month reported on and also for the corresponding month of the previous year, for comparison. These reports covering the operation for the one year of the contract are given from page 58 to page 105 inclusive.

These reports show the uneconomical conditions that may exist in a plant presumably well designed and well operated, and also what may be accomplished in improvement by searching out the faults and bringing persistent pressure to bear to correct them. Attention is called to the two boiler tests cited in the first report to illustrate the gain by proper operation over improper operation.

The results obtained in this particular case were not the maximum possible. That could not be expected when only one day in the month was spent in the plant and dependence was placed on

the operatives to act on instructions during the remainder of the time. Never the less, the results were quite gratifying and indicate what may be accomplished.

One point should be particularly emphasized in work of this kind - that is the human element. Interest of the operatives must be obtained, their co-operation must be secured, and they must be educated. If the operatives are not interested, they will not co-operate, and without their co-operation it is extremely difficult to secure results, and results are limited. The operatives may know how to operate a plant to produce the output, and they usually pride themselves on continuity of output, but very few know the principles of power plant efficiency. Most of them are willing to co-operate and to learn, but, and this is the crux of the problem of the human element, no man can secure their interest and co-operation and give them the necessary information by assuming an attitude of superiority. It is necessary to have an attitude towards them such as they have toward each other.

It is the purpose of this writing to show some of the faults common to power plants which result in inefficient and uneconomical operation, to show how these faults may be remedied, and to use a concrete case of an actual example to show how these things were done in a practical engineering way. For that reason, the original reports covering the case of the Buhl investigation and inspections are given verbatum.

These reports together with this Introduction, give the history of the case, the reports tell what was found and what was done, and the Summary gives the final results obtained, although individual reports give the results for individual months.

It should be stated that these reports were written for men having no technical training or knowledge.

## DESCRIPTION OF THE PLANT

The diagram on page 9 shows the plan of the plant. Coal is delivered to the rear or north side of the plant, by an elevated railroad spur, from which the coal is dumped on a concrete floor. The coal is brought into the plant in small cars of about 3000 pounds capacity each, over a light track of about two feet gauge. The coal is weighed over a track scale (21) and the car is then elevated to an upper track by a hydraulic lift (20). From the upper track (15), it is dumped into the hoppers of the various stokers.

At the time of the first investigation, boiler No. 5 (17) on the diagram, was not in place but was contracted for; the feed water heater and V-notch meter (7) had not been purchased; the feed pumps were located between the boiler wall (9) and the building wall and an old feed water heater and meter were located in this space.

During the period of inspection the feed pumps were moved, the old feed water heater and meter were discarded, and the new heater and meter (7) installed, and the boiler (17) installed.

The electrical load and pumping load is the entire load during the summer months, but during the heating season of about nine months, the heating load becomes by far the greater part of the plant load. During the summer months, exhaust steam is turned into the mains for use by customers for heating water, and in the late spring and early fall, exhaust supplies the heating demand, but during the colder months, the bulk of the live steam is used for heating.

The tabulation on page 7 describes the plant equipment in detail.

1. Chuse non-releasing corliss engine, 18" x 24", 200 R.P.M.

2. Electric Machinery Co. A.C. Generator, 250 K.W., 2400 V., 60 cycles, 3 phase.

3. Chuse four valve engine, 13" x 14", 275 R.P.M.

4. Electric Machinery Co. A.C. Generator, 75 K.W., 2400 V., 60 cycles, 3 phase.

5. Sullivan Machinery Co. air compressor, two stage, 14" x 16" x 10" x 16".

6. Electric switch and instrument board.

7. Cochrane feed water heater and Lea V-notch meter. Capacity 45 000 pounds of water per hour.

8. Gauge board.

9. Boiler No. 1. 150 H.P., H.R.T.

10. Boiler No. 2. 150 H.P., H.R.T.

11. Boiler No. 3. 150 H.P., H.R.T.

12. Model automatic stoker.

13. Model automatic stoker.

14. Model automatic stoker.

15. Track for running small coal cars above stoker hoppers.

16. Boiler No. 4. 350 H.P., Casey-Hedges horizontal water tube.

17. Boiler No. 5. 350 H.P., Erie City cross drum vertical water tube.

18. Detroit automatic stoker.

19. Model automatic stoker.

20. Hydraulic elevator for lifting coal cars.

21. Track scale platform.

22. Track scale weighing beam.

23. Marsh vacuum return pump, 8" x 10" x 12".

24. Marsh vacuum return pump, 8" x 10" x 12".

25. Burnham vacuum return pump, 16" x 20" x 24".

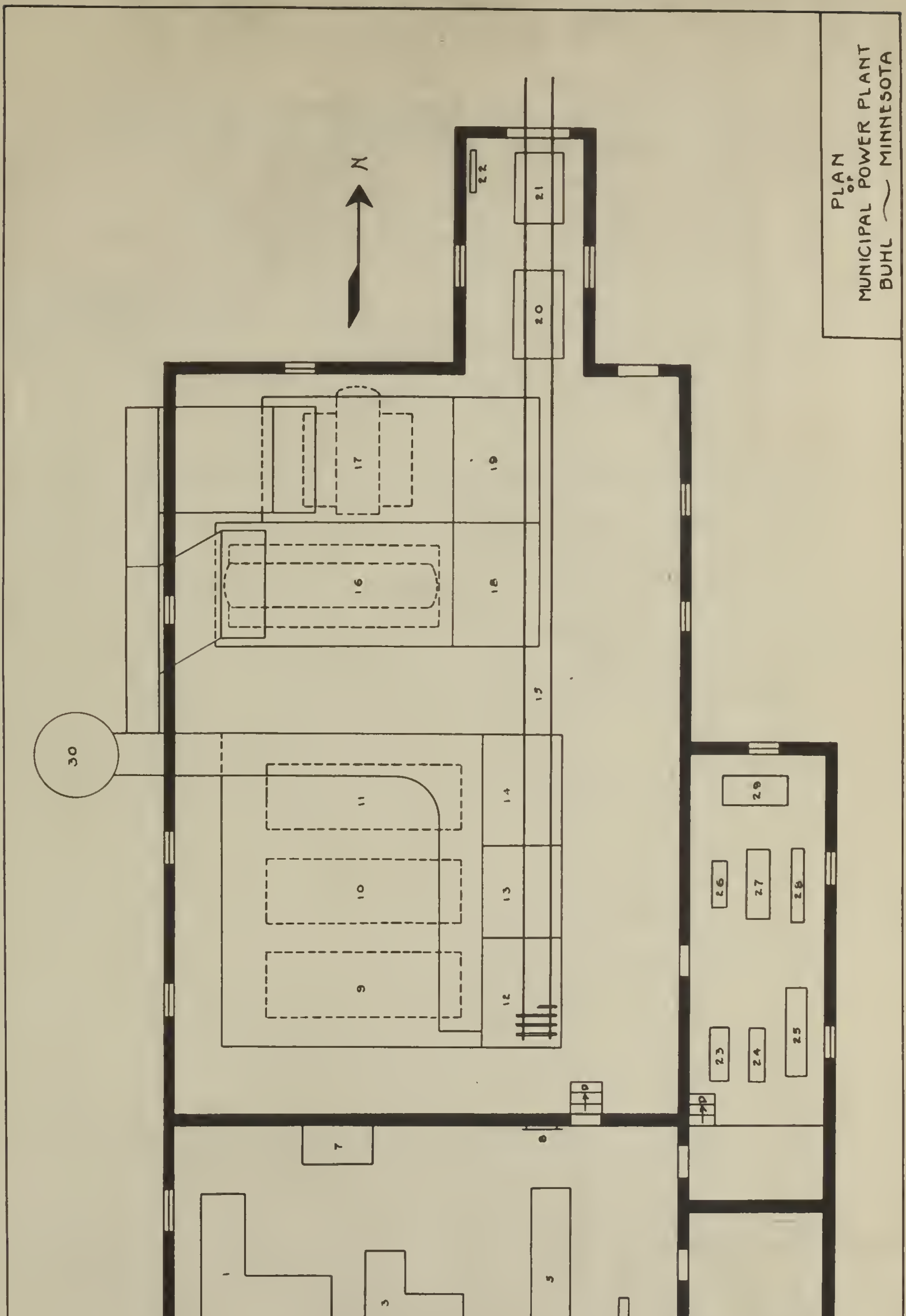
26. Dean boiler feed pump, 8" x 5" x 12".

27. Mc Gowan duplex boiler feed pump, 10" x 6" x 10".

28. Dean boiler feed pump, 6" x 7" x 12".

29. Prescott fire pump, duplex, 12" x 7" x 12".

30. Concrete chimney, 60" x 185'-0".


PLAN OF MUNICIPAL POWER PLANT
BUHL — MINNESOTA
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# LETTER OF TRANSMITTAL

Honorable W. J. Doyle,
President, Board of Trustees,
Village of Buhl,
Minnesota.

Honorable Sir:-

In accordance with your instructions, we have made an investigation of your power plant and heating system to determine the present efficiency of steam generation in the boiler plant, and the efficiency of utilization of steam as generated, the object of the investigation being to bring to your attention existing losses and means for their elimination.

The report covering this investigation is hereto attached.

Very truly yours,

CHARLES L. PILLSBURY CO.

By O.C.

Minneapolis,

September 17th, 1918.

# REPORT ON INVESTIGATION
# to
# DETERMINE MEANS OF FUEL SAVING
# in the
# MUNICIPAL PLANT
# VILLAGE OF BUHL, MINNESOTA.

-0-

The object of this investigation was to determine the existing losses in the generation of steam and in the utilization of the steam generated, in the Municipal Heat, Light and Water Plant and System of the Village of Buhl, Minnesota. The investigation was made, first, as to production within the plant, and second, as to utilization outside of the plant.

Points considered in connection with production were:

1. Furnace Operation
2. Condition of Boilers
3. Equipment
4. Management of Plant

Points considered in connection with utilization were:

1. Condition of Equipment outside of plant
2. Use of Service by Consumers.

The discussion of the above points will be taken up in the order named.

## PRODUCTION

### Furance Operation

The largest loss in most power plants is due to inefficient combustion of the fuel, and mixture of the furnace gases with infiltrated air. If the boiler walls, setting, etc., are made air

tight, a most reliable check can be kept on the furnace operation by means of analyses of the gases evolved.

It is absolutely essential that the grates should be covered at all times. Too much stress can not be put upon this most important point. If the number of boilers in operation makes this impossible, the number should, by all means, be reduced. With the grates covered with fuel, the amount of fuel burned, which of course, should be in proportion to the load carried and amount of steam produced, should be controlled by the amount of air admitted into the furnace. This amount of air, in turn, should be controlled by the damper in the boiler uptake.

With a given thickness and kind of fuel covering the grates completely, the amount of air passing thru would be determined by the draft in the furnace. The fireman should learn to control the rate of conbustion by the air supply, should learn the relation between this air supply, condition of fuel bed and furnace draft, and should learn the means of obtaining the proper draft by damper control. The present firemen in the plant have been instructed in damper operation and use of the draft gauges, and have shown aptitude in learning. They require practice and interested supervision.

A source of loss in furnace operation is the unconsumed combustible in the refuse. This may, in some cases, be quite serious, but as it is a visible loss, it is more usually prevented. It is impossible to prevent some loss in this way, and what might appear as a large percentage of combustible in refuse as based on refuse, would really be a small percentage as based on combustible in coal. The coal was found to be very satisfactorily burned.

The invisible loss, the loss up the stack, was the large loss found in operation of the boiler furnaces. The load carried on the boilers was too small, in comparison with the capacity of boilers. This would make it practically impossible to keep a proper fire on the grates. At most times the grates were found to have large bare spots, at times exceeding more than one half the grate area, thus allowing an enormous amount of air to pass thru, performing no function other than absorbing heat and carrying it out the stack. At the same time, it was found that the dampers were kept wide open, thus casuing more air to be passed and more heat to be lost than if the dampers had been throttled. It was also the practice of the firemen to open the furnace doors allowing air to pass over the fires, whenever the safety valve blew, in order to relieve the pressure. This practice results in increased loss up the stack, and also subjects the metal and brickwork to severe strains due to contact with cold air.

The accompanying curve sheets show that the higher the load carried on the boilers in operation, the higher the efficiency, as indicated by the evaporation per pound of coal. These curve sheets will clearly indicate to you, and to your plant operators, just what correct operation should be. In the cases where the higher loads were carried on the boilers, a better fire was carried on the grates and the grates were more thoroly covered, thus cutting down the stack losses.

The same point is proven by two evaporative tests which were made. In the first test, in which two boilers were operated, and were operated in the same manner as in vogue at your plant in the past, the evaporation was six pounds of water per pound of coal,

and the average gas analysis showed a carbon dioxide content of 4.4%. In the second test in which one boiler was operated, and that at a greater loading than the two combined in the previous text, and in which care was taken to maintain proper furnace conditions, the evaporation was eight and one fourth pounds of water per pound of coal, and the average gas analysis showed a carbon dioxide content of 13.7%.

These tests were made to indicate the difference between proper operating conditions, as maintained during the second test, and improper operating conditions which were typical of the manner in which the operations were performed in the past.

Flue gas analysis is the only true means of determining the efficiency of combustion in the furnace. If the carbon dioxide as indicated by the flue gas analysis is low, that is proof positive that heat is being uselessly lost up the stack.

### Condition of Boilers

The boiler proper, and by that is meant the metal containing the water and steam and thru which heat must be transferred from the gases, should be kept in as clean a condition as possible. Metal will conduct heat quite rapidly from hot gases on one side to the water on the other provided there is nothing to prevent the contact of the water and gases with the metal. However, if scale exists on one side of the conducting metal or soot deposits exist on the other, an enormous resistance is offered to the passage of heat.

The water fed to a boiler should be as clean and contain as few impurities as possible. Scale deposit on tubes is due to scale forming substances in water. If the water can not be softened before being fed, the scale formation should be prevented by

judicious use of boiler compound. Certain impurities in water will cause foaming and priming, the effect of which is to carry water over with the steam into the steam pipes. Among these impurities are soapy matter and vegetable matter. There is always an element of danger to engines when water is carried over, and in any case it is desirable to have steam as dry as possible.

Impure water containing soapy substance was found at times coming in the return from the mains which had been cleaned of grease with a compound of sodium carbonate. The chemical reaction of the carbonate and grease resulted in soap. The remedy in such a case is to clean such water from the boilers and prevent its entrance, rather than as was done by the power plant operators, to put more boilers into service, so that the steaming rate would be too low to prime the steam with water.

The boiler tubes were found to be satisfactorily clean from scale due to the recent use of compound by Mr. Miller, However, a hand lance is used on the return tubular boilers for blowing soot, and this is not a satisfactory method as the operation is not thoro, not sufficiently frequent, and subject to neglect.

The brick setting surrounding the boilers should be free from any cracks thru which air could possibly pass. Even if no cracks exist, brick are quite porous and will pass a large amount of air thru these pores. The effect of this air is the same as that coming thru holes in the fire, that is, to take up heat, otherwise available for making steam, and carrying it up the stack. Mr. Miller has been working in the right direction in that he has been filling cracks and painting the walls with a plastic to seal the cracks and pores.

## Equipment

Soot and fly ash has a tendency to accumulate in the breeching and retard the flow of gases. If boilers are to be operated at desirable capacities, the breechings should be kept clean. A very large amount of soot and ash accumulation was found in the breechings, which was cleaned out.

It is quite essential the boilers be equipped with properly constructed dampers with proper arrangement for their manipulation. If dampers do not close tightly, air will be passed into the breeching from the boilers not in operation, cooling down the stack temperature and thus reducing the available draft for carrying the load on the boilers operating. The temperatures of the gas passing to the stack was found to be as low as 200 degrees F.

The purpose of building a stack of any particular height is in order that a draft corresponding to that height may be obtained. Anything cutting down the draft counteracts the effect of the stack and a considerable portion of the expenditure in the stack is rendered useless.

As was previously referred to under "Furnace Operation", damper manipulation is necessary to obtain proper and efficient combustion of the fuel. Means must then be provided by which the firemen can set the dampers to any desired opening, and retain them in any given position.

The damper on Boiler No. 4 is vertically hinged, making it extremely difficult to turn, and no proper means are provided for its manipulation. This damper will not close tightly.

The dampers on the return tubular boilers do not fit properly, allowing a large amount of air to pass even when closed. Chains

are installed to move them, but they are constructed in such a way that they stick in place, and it is very difficult to operate same. If proper means of manipulation are not provided, the firemen can not be expected to take interest in their setting.

## Management of Plant

The success of any enterprise depends on interested and competent management. If real interest does not exist, success can not be expected. This is particularly true of a power plant. The man who is directly responsible for the management, organization and operation of a plant should understand the fundamental principles of power plant operation, should be continually seeking improvements in methods of operation, should see that his operatives work to produce the most efficient results, and should be a student of the literature of his profession. Personnel and personality are prime requisites.

The results of the investigation indicate that management of the Buhl plant is very slack and lax. There is not the proper coordination and systematizing of operations, and proper supervision is not exercised over the employees. This is clearly indicated by the condition of equipment, the methods of operation, particularly boiler operation, and the fact that no advantage is taken of available opportunities to improve the load factor of the plant. As an example, the air compressor, which consumes a large amount of steam, was put into operation during the peak electrical load, although no immediate necessity existed. The air compressor should not be operated except at times when the other demands are low, so that the load on the boilers is more even. It must, of course, be understood that sufficient water must be pumped into the

reservoir, before the electrical peak comes on. This is simply a matter of management.

## UTILIZATION

### Condition of Equipment Outside of Plant

In a district heating system such as that in Buhl, the losses in transmission are necessarily high, on account of the amount of main pipe required per consumer. For this reason, the steam in those mains should be protected by covering. There are some mains which are not properly covered, and there are a number of houses having bare distribution pipes underneath, resulting in a large loss of heat.

Some time ago the oil separator was taken from the exhaust line, resulting in mains, service pipes, radiator connections and returns becoming clogged with grease. This, of course, made heating much more difficult and required the carrying of more pressure on the mains. Mr. Miller has installed an oil separator now, and is getting the grease cleaned from the heating system as rapidly as possible. This grease has also been the direct cause of the failure of the condensation meters to operate.

The power plant records indicate that from June 1917 to June 1918, the plant evaporated 109,000,000 pounds of water in the boilers. Of this, 81,500,000 pounds would be a conservative estimate of the amount of condensation from radiation which would be indicated by meters. This is based on allowance of:

| | |
|---|---:|
| Non heating season ...................... | 13,500,000 |
| Loss in engines ........................ | 5,000,000 |
| Loss in transmission ................... | 9,000,000 |
| | 27,500,000 |

The records in the Recorder's office show a total of 77,800 square feet of radiation in service during the past heating season. The condensation per square foot of radiation for the season was, therefore, 1050 pounds. This is extremely high. The amount of condensation, under conditions such as exist in Buhl, should be not over 700 pounds per square foot of radiation. This high rate of condensation is evidently due to careless use of steam by consumers and this in turn is encouraged by the flat rate charge for steam.

If a charge for steam was made on a basis of actual amount used, consumers would use only the amount necessary for comfort, and would take steps to prevent useless waste, in as much as they would have to pay for the steam wasted.

It is possible for consumers to reduce consumption by not heating rooms to a higher temperature than necessary, by not having radiators on and windows open at the same time, by not heating rooms which are not in use, by not heating bed rooms and rooms not constantly used, to as high a temperature as living rooms, by not allowing hot water to waste by leakage, and by covering all pipes under the house and in basement. A meter rate for steam would be the greatest incentive towards effecting these economies.

The average water consumption per day from June 1917 to June 1918 was 220,000 gallons. On a basis of an assumed population of 1700, this would amount to an average per capita per day consumption of 130 gallons. This rate is high - 75 gallons per capita per day would be a very liberal allowance.

A meter rate would tend towards a saving of water as a meter rate for steam would tend towards saving steam, but there are difficulties in the use of water meters, and it is questionable if

their use would be advisable. Protection from freezing would be the greatest difficulty. Every effort however, should be made to reduce water consumption, particularly during the summer time when water waste causes a greater fuel waste than during the heating season, when the exhaust steam from the air compressor is available for heating.

A considerable saving could also be made in the white way lights. At present 100 watt lamps are used in the upper globes and 60 watt lamps in the lower globes. These lights require 25 kilowatts. If 40 watt lamps were used in place of the present 100 watt, and 25 watt lamps were used in place of the present 60 watt, the power required would be reduced to 10 kilowatts. The smaller lamps would give sufficient light. As an example of a change of this kind, it might be cited that Hibbing is using the 40 and 25 watt lamps at present in their white way.

## RECOMMENDATIONS

### Furance Operation

Care should be taken to carry loads on the boilers comparable to their capacity. In no case shall two or more boilers be operated when it is possible to operate with a fewer number. The load on any boiler in operation should at any time be at least equal to the rating of the boiler.

The firemen should at all times keep the grates covered with fuel and never allow holes or cracks to form in the fuel bed. The control of the rate of combustion should be by damper setting using the draft gauges for intelligent setting of the dampers. Damper control, use of draft gauges and maintenance of proper condition of fuel bed should be emphatically impressed on the firemen.

They should be required to give these points their utmost and constant attention, else there will certainly be a great waste of coal.

Samples of the furnace gases should be collected in a gas collector, and analyzed at least once each day. If this could be done once each shift or oftener, the results would be better.

It would be well to install a bonus system for the firemen, which would result in more pay for higher percentages of carbon dioxide in the furnace gases, the extra amount to be in proportion to the carbon dioxide content.

A system of bonus payment could be worked out with the use of the following table:

| Percentage $CO_2$ | Multiplying Factor |
|---|---|
| 6 | 0.0 |
| 7 | 0.0040 |
| 8 | 0.0072 |
| 9 | 0.0105 |
| 10 | 0.0114 |
| 11 | 0.0128 |
| 12 | 0.0142 |
| 13 | 0.0153 |
| 14 | 0.0163 |
| 15 | 0.0173 |

To use this table, the multiplying factor, corresponding to any given average of $CO_2$, would be multiplied by the number of tons of coal consumed during the interval of time during which the $CO_2$ was taken, and for which the $CO_2$ was averaged, and this product in turn multiplied by the value of the coal per ton. The overall product would be the amount of the bonus.

For example, assume that the $CO_2$ for one month averaged 12%, the coal consumption during the same month 1000 tons, and the value of the coal $7.00 per ton. The multiplying factor for 12% $CO_2$ is 0.0142. The amount of bonus would then be 0.0142 x 1000 x 7, or 99.5 or $99.50 which could be divided equally among the firemen.

If analyses should be made on samples of gas collected during each shift, a separate bonus could be calculated for each individual fireman. The advantage of dividing the bonus equally lies in the fact that if any one fireman is not operating his furnaces properly, he is causing a loss of money to the other firemen, and that they will furnish an additional incentive, besides his bonus, to do better work. The advantage of keeping a record of the results of each fireman and paying each in accordance with the results he obtains, is that it produces competition.

In case the number representing the average $CO_2$ is not an integral number, the multiplying factor may be obtained by interpolation.

The table is calculated on the basis that one tenth the saving in coal by obtaining carbon dioxide contents above 6%, is paid to the firemen as a bonus. That is, the maximum amount of coal is assumed to be burned when the carbon dioxide is 6%, and the difference between the coal burned with 6% $CO_2$ and coal burned with any higher $CO_2$ being the saving in coal, the difference in coal burned being proportional to any given $CO_2$ percentage and 6% $CO_2$.

The saving due to proper operation is indicated by the results of the two tests previously referred to, the data of which is attached. The rate of evaporation per pound of coal was increased from six to eight and one fourth, while the carbon dioxide was increased from 4.4 to 13.7. With the plant in proper condition, still better evaporative results may be expected. This increase is equivalent to a saving of 27½%. Based on a coal bill of $70,000.00 per annum, the saving effected amounts to $19,200.00 per annum.

## Condition of Boilers and Equipment

The boiler walls are at present in fair condition, one coat of plastic covering having been put on. The walls and tops should be gone over very carefully and all places sealed, thru which air can leak. The whole should be covered with at least one more coat of plastic covering. Special attention should be given to joints between iron parts and brick work.

The tubes should be kept free from scale on the water side. A stock of good boiler compound should be kept and used in sufficient quantity to prevent accumulation of scale. Care should be taken, however, not to use excessive quantities of compound as the result would be detrimental to the boiler operation.

The tubes should be kept free from soot on the fire side. The present method of using a hand lance is not effective and cleaning is not done with sufficient frequency. Mechanical soot blowers should be installed on the three return tubular boilers, and these used to blow the flues at least three times daily. The installation of soot cleaners will return their total investment in one year. It would also be well to install a blower in the breechings to prevent accumulation of soot deposits.

The portion of the breeching within the boiler room is covered with magnesia, but the portion between the building and the stack is bare. This bare part should be covered, as the losses there would be greater than from bare breeching within the boiler room.

The turn in the breeching above No. 3 boiler should be reconstructed with a long radius curve on the inside, as the present loss of draft in this turn is two tenths of an inch, or one third

the total stack draft.

### Equipment

New dampers should be placed in all the boilers to enable closing complete and operating with ease. These dampers should be provided with levers and rods in order that the firemen can set them in any given positions. The question of design of these dampers and rods and levers has been discussed with Mr. Miller.

It is contemplated, at present, to place the new feed water heater next to the south wall in the boiler room, in the present location of the two feed pumps. This location would not provide sufficient head on the pumps, and would also be such as to render it difficult to clean the heater. A better place for this heater would be in the engine room next to the north wall. It would then have sufficient elevation above the pumps and would receive better attention.

The present feed water weigher seems to be inoperative, and no action has been taken to provide means for weighing the feed water in connection with the new heater. Weighing and recording the feed water is quite essential, and it would be a serious mistake if means were not taken for weighing.

### Management

One man in the plant should be responsible for taking samples of furnaces gases, analyzing them for carbon dioxide, and making records of the carbon dioxide, the gas temperatures, and the furnace and uptake drafts.

The Superintendent should give hearty co-operation in getting into effect all the recommendations tending towards fuel saving. He should give constant supervision to the plant employees and see

that each one does his part in the fuel conservation program. He should be so acquainted with the fundamental principles of efficient operation as to be able to instruct and supervise his men in such a way as to get most effective results.

He should have the plant and its operation systematically organized. He should give attention to all wastes and leaks, and maintain constant vigilance to prevent them.

The Superintendent is responsible for the expenditure of approximately $70,000.00 a year for fuel, as well as expenditures for salaries, supplies and new equipment. This means putting into one man's hands the expenditure of a very large amount of money, and he should be capable of expending it with the least possible waste.

The Superintendent should have his force of men so organized as to obtain complete co-operation between all the men. They should all work for the same result, the production of the plant's necessary output with the least cost in fuel. Co-operation is absolutely essential in a plant to obtain efficient operation, and any employee who opposes methods of conservation and efficiency is a liability rather than an asset. The Superintendent should see to it that his men are boosters, and that they are co-operative, rather than working at cross purposes.

## Equipment Outside of Plant

All the steam piping should be thoroly cleaned of grease deposits. Mr. Miller is at work on this at present. All of the condensation meters should be thoroly cleaned in a boiling solution of boiler compound. Attention should be given to the meters to make certain they remain clean in the future, and in operating

condition.

All pipes carrying steam of return condensation, not actually in rooms to be heated, should be covered to prevent radiation losses. Particular emphasis should be put on the necessity of covering pipes in basements and under buildings having no basements.

## Use of Steam, Water and Electricity

Steam should be sold on a meter rate, a rate being made in terms of so many cents per one thousand pounds of steam condensation as measured by the meters. This recommendation is emphasized, and should be put into immediate force.

The matter of economical use of steam should be forcefully brought to the attention of the users. It should be brought to their attention that 68 degrees F. is maximum temperature to which living rooms are to be heated, as stated by the United States Fuel Administration, that rooms not used should not be heated, that rooms not used continually such as bedrooms, should be heated to a lower temperature than living rooms, and that steam should always be shut off from radiators when the windows are open. Persons flagrantly wasting steam should have the service disconnected, and should be denied the use of municipal heat.

The amount of water used should be reduced. Warning should be given that any consumer wilfully wasting water by permitting leakage thru toilets or faucets, or by allowing water to flow uselessly, shall have the water service discontinued.

The size of the lamps in the white way standards should be reduced. The present 100 watt and 60 watt lamps should be replaced by 40 watt and 25 watt lamps respectively.

## RECAPITULATION

Condition of plant and system existing at beginning of investigation:

### Boiler Plant

Boilers in service not coordinated with load.

A graphic tabulation was prepared for each month indicating:

- Horse power of boilers in operation
- Percent of boiler rating developed
- Evaporation per pound of coal

By reference to these sheets it will be noted that the boiler horse power developed varied from 57 to 90% of boiler rating.

Boilers operate best when above rating. A 150% point is not too high. When operating at low rating, inefficiency results.

Boilers fairly clean of scale but not clean of soot. A dirty boiler retards transfer of heat from hot gas to water, resulting in inefficiency.

Uncovered grates - Cause large loss of heat up stack due to heating excess air.

Opening fire doors to relieve pressure. This practice causes waste thru heating excess air and causes strains on boiler due to change of temperature.

Uptake dampers not utilizable. Important that air supply be controlled by draft regulation.

Dampers leaking in dead boilers. Causes reduction of draft in boilers in operation.

Leaky boiler settings - causes infiltration of air and results in waste of fuel.

Soot in breeching. Retards gas flow and causes reduction in draft.

Uncovered breeching. Cools gases to stack, reduces available stack draft.

Bad water in boiler. Impurities in boiler feed water cause foaming and priming.

### Management

Supervision lacking. Important that Superintendent has knowledge of fundamental principles of efficient operation, giving precise and specific directions, and maintaining spirit of co-operation of operatives.

### Distribution System

Mains uncovered.

Mains, services and meters clogged with grease.

Meters inoperative.

Flat rate system in vogue.

Consumers' heating rooms to excessive temperature.

Consumers opening windows while radiators are left on.

Water used extravagantly.

## RECAPITULATION - RECOMMENDATIONS

Operate boilers at 130% rating or better.

Keep boilers clean of soot and scale.

Keep grates well covered.

Do not open fire doors to relieve pressure but operate uptake damper.

Operate uptake damper to correspond with draft required.

Repair leaky dampers.

Clean breeching of soot and ash.

Change breeching to avoid loss of draft in bend.

Install mechanical soot cleaners in boilers.

Install mechanical soot cleaner in breeching.

Install waste gas economizer.

Use boiler compound judiciously.

Install water weighing or measuring device.

Establish bonus system in boiler room.

Frequent flue gas analysis and record readings.

Install draft gauges and record readings.

Install uptake thermometer and record reading.

Extend record system.

Cover mains and services.

Clean mains and services of grease.

Establish meter rate for steam consumption.

Cut down wattage of street light.

Cut down use of water.

We have indicated how the fuel cost was reduced 27½% by boiler operation alone, corresponding to a possible saving of $19,200.00 per year. With the establishment of a meter rate which will greatly reduce the steam output, it is not exaggerated to say that a net reduction of $25,000.00 can be made in your yearly fuel bill, and the comfort and convenience of the consumers be continued as at present.

Respectfully submitted,

Minneapolis
September 17, 1918.

CHARLES L. PILLSBURY CO.
By O.C.

## Results of Test - August 29th 1918.

| | | |
|---|---|---|
| Number of boilers in operation | 2 | |
| Horse power rating of each boiler | 150 | |
| Total rated horse power in operation | 300 | |
| Average steam pressure (gauge) | 114 | lbs per sqin. |
| Average feed water temperature | 150 | degrees F. |
| Average draft in uptake, Boiler No. 1 | .26 | inches |
| Average draft in uptake, Boiler No. 2 | .29 | inches |
| Average $CO_2$ in rear combustion chambers | 4.4 | % |
| Total water fed | 43,750 | lbs. |
| Total coal fired | 7,268 | lbs. |
| Evaporation - pounds of water fed per pound of coal fired | 6 | |
| Horse power developed | 170 | |
| Percent of rating developed | 56.7 | |

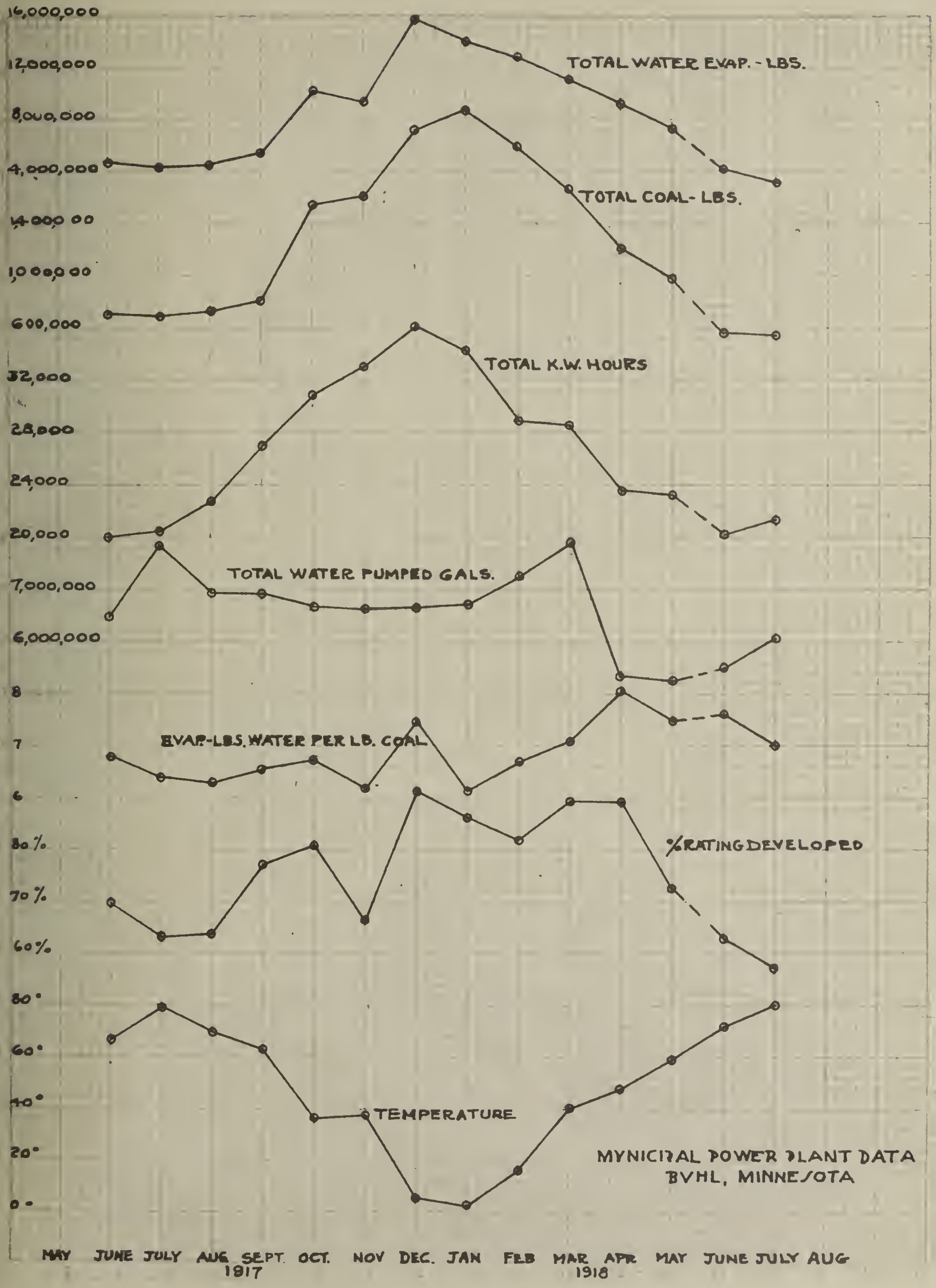
When the above test was made, the boilers were operated as was customary in the past, as it was desired to get definite data as to the efficiency of the methods of operation. No care was taken to keep grates covered and, in fact, they were bare over a considerable portion of their area. The dampers were wide open at all times, not only in the boilers in operation but also in the boilers not in operation. Whenever pressure was raised to such a point as to blow the safety valve, the firemen opened the furnace doors to cool down the furnaces and boilers and reduce the pressure.

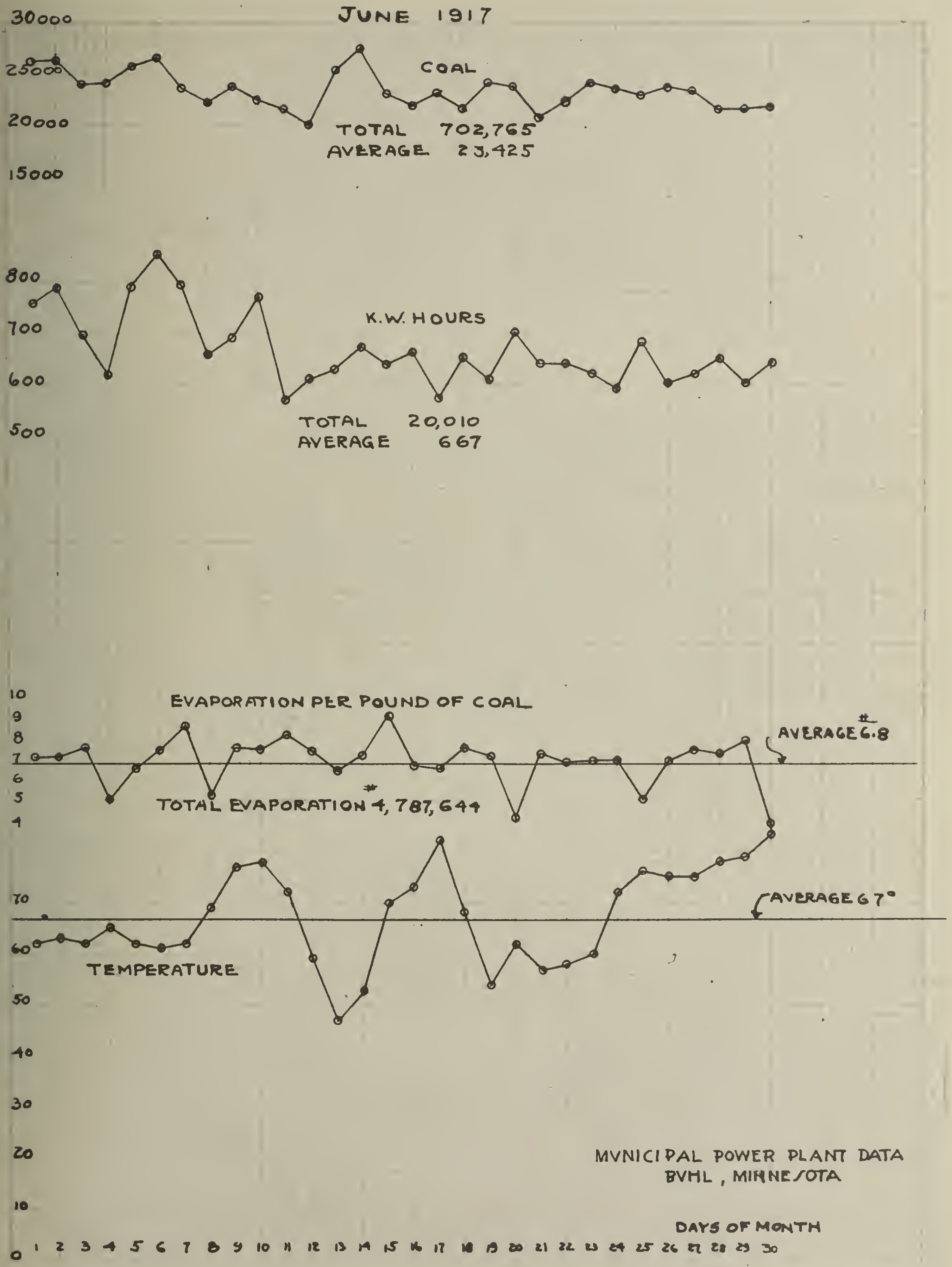
## Results of Test - September 6, 1918.

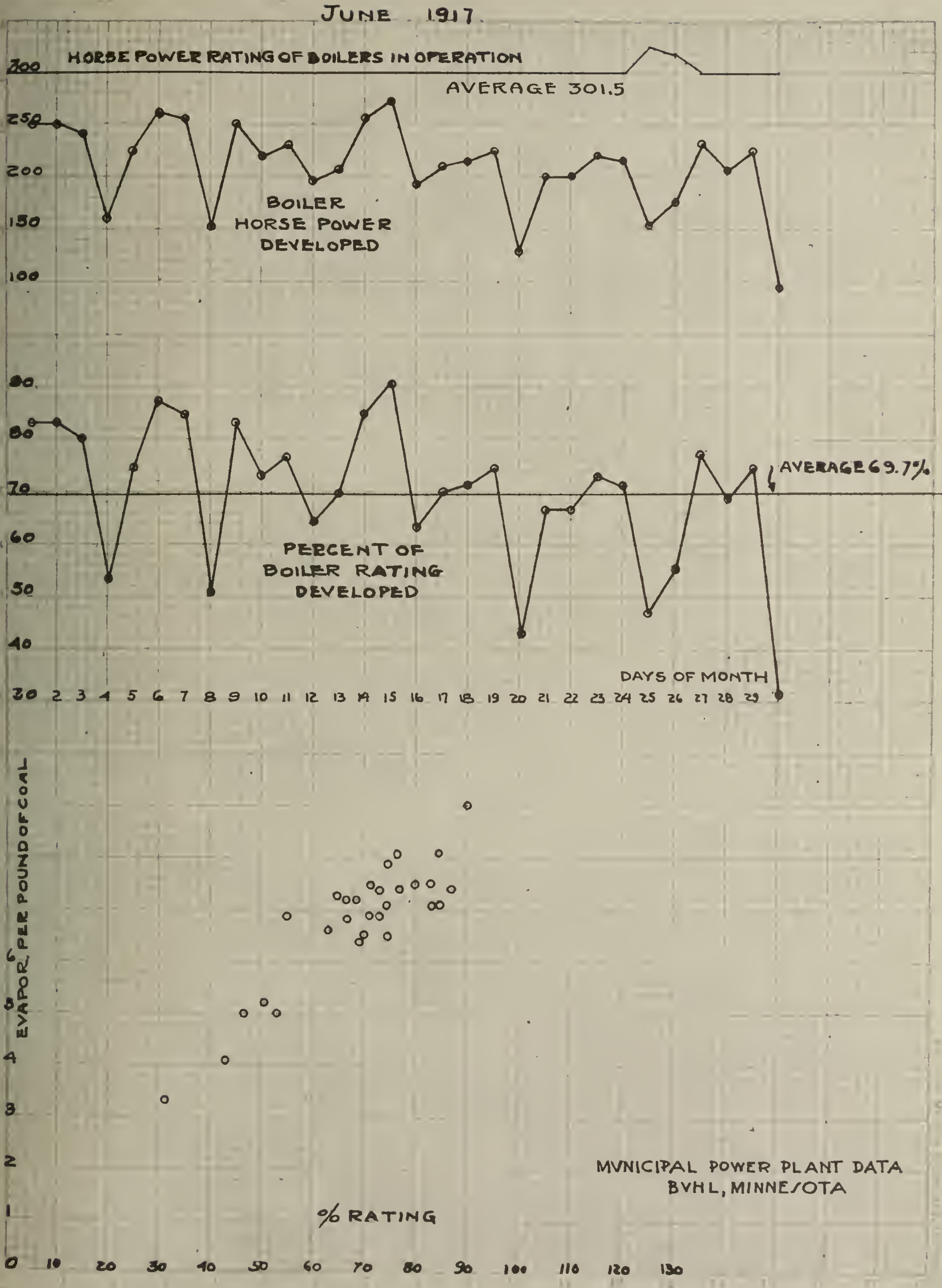
| | | |
|---|---|---|
| Number of boilers in operation | 1 | |
| Horse power rating of boiler | 150 | |
| Average steam pressure (gauge) | 107.3 | lbs per sqin. |
| Average feed water temperature | 145 | degrees F. |
| Average draft in uptake | .23 | inches |
| Average draft in furnace | .10 | inches |
| Average $CO_2$ in rear combustion chamber | 13.7 | % |
| Total water fed | 43,928 | pounds |
| Total coal fired | 5,344 | pounds |
| Evaporation - pounds of water fed per pound of coal fired | 8.25 | |
| Horse power developed | 189 | |
| Percent of rating developed | 126 | |

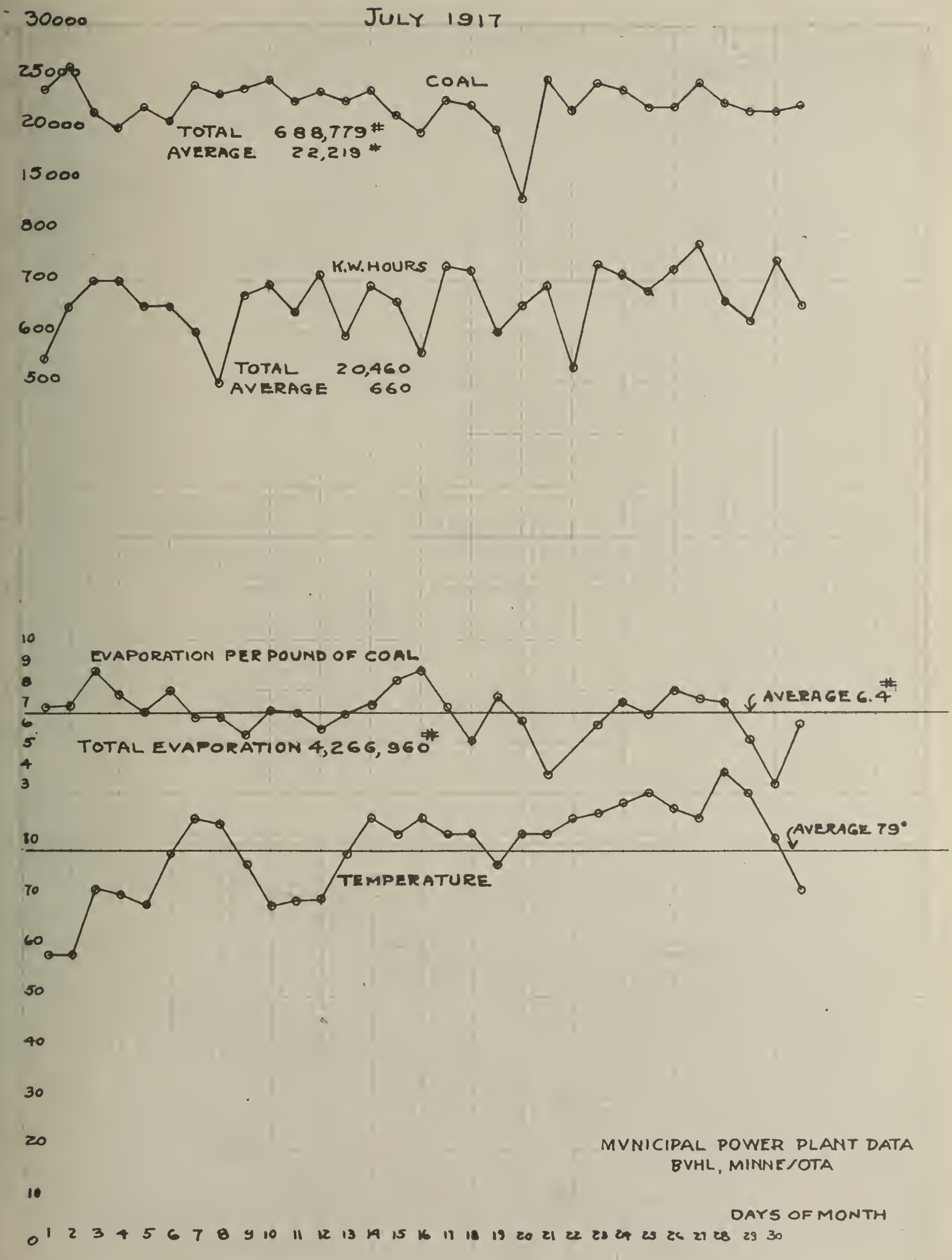
During the above test, care was taken to keep the grates covered with fuel. The damper on the boiler was operated to pass air in proportion to the load on the boiler. The dampers in boilers not in use were closed as well as possible.

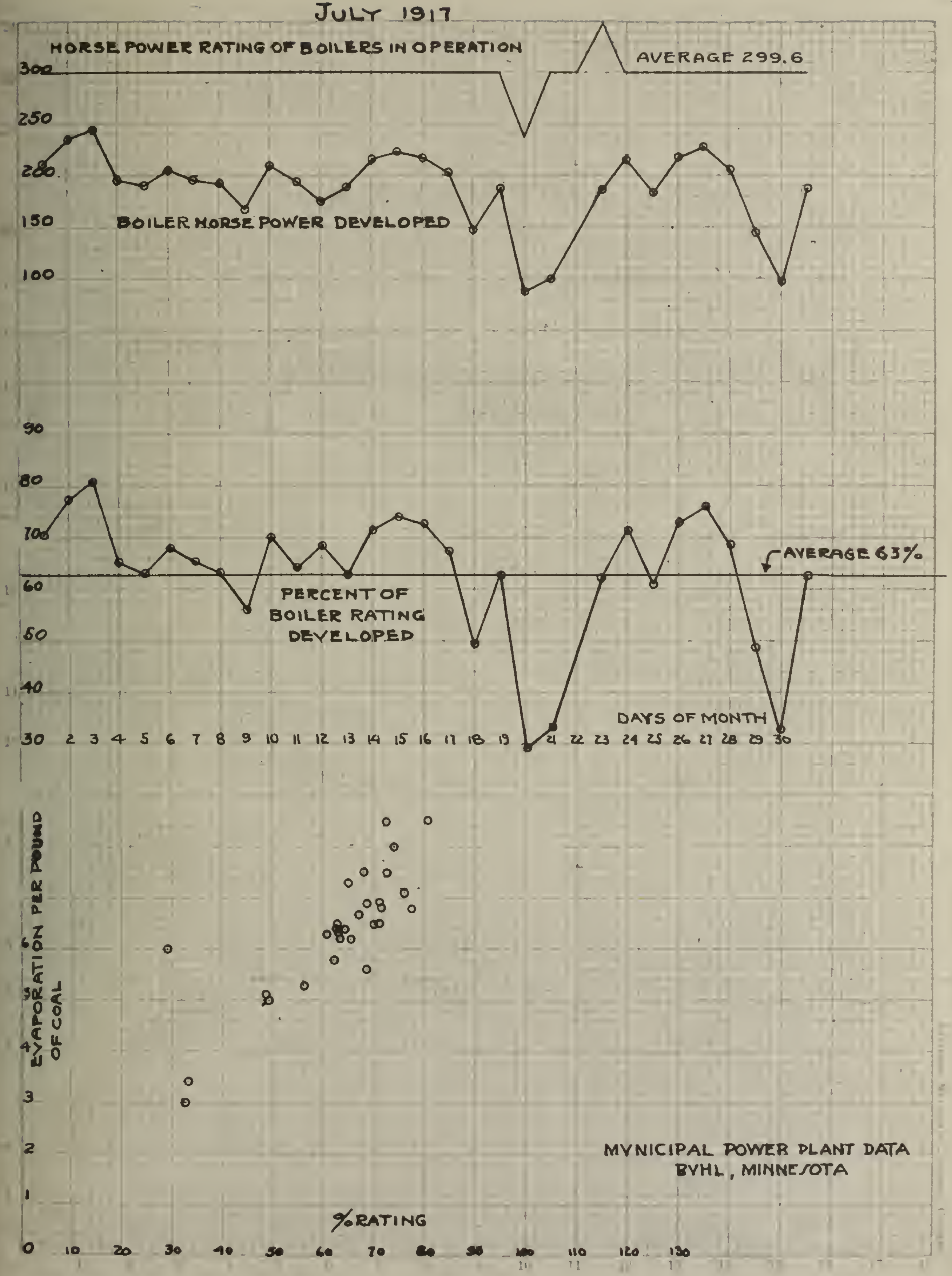
Difficulty with the feed pumps was encountered during the test, due to their becoming air bound and failing at times to supply sufficient water to the boiler. This load in this case was limited by the pumps, and could have been carried higher if the pumps had operated properly.

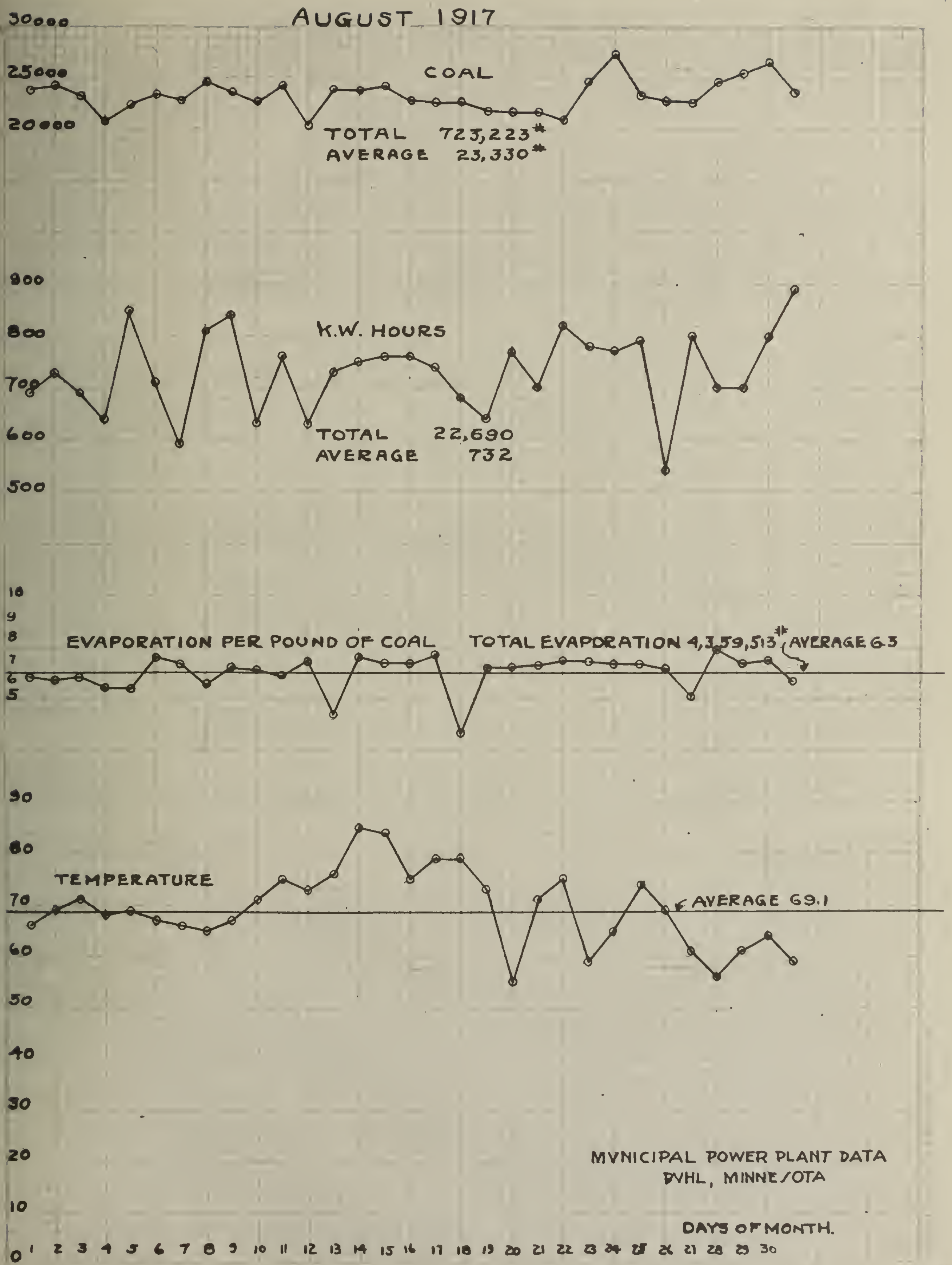

16,000,000
12,000,000
8,000,000
4,000,000
1,400,000
1,000,000
600,000
32,000
28,000
24,000
20,000
7,000,000
6,000,000
8
7
6
80%
70%
60%
80°
60°
40°
20°
0°
TOTAL WATER EVAP. - LBS.
TOTAL COAL - LBS.
TOTAL K.W. HOURS
TOTAL WATER PUMPED GALS.
EVAP.-LBS. WATER PER LB. COAL
% RATING DEVELOPED
TEMPERATURE
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA
MAY
JUNE
JULY
AUG
SEPT.
OCT.
NOV
DEC.
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
1917
1918

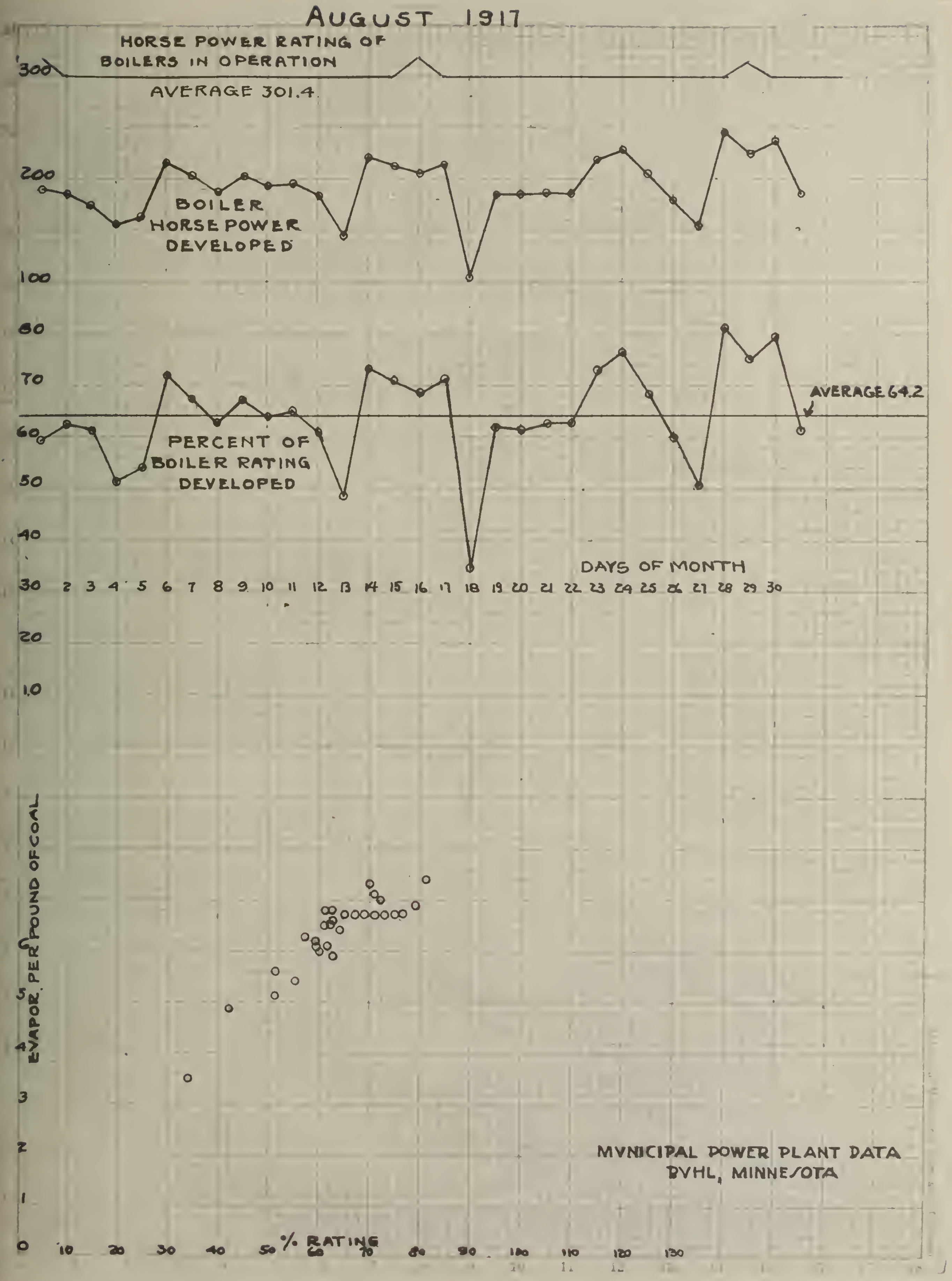

JUNE 1917
30000
25000
20000
15000
COAL
TOTAL 702,765
AVERAGE 23,425
800
700
600
500
K.W. HOURS
TOTAL 20,010
AVERAGE 667
10
9
8
7
6
5
4
EVAPORATION PER POUND OF COAL
AVERAGE 6.8#
TOTAL EVAPORATION 4,787,644#
70
60
50
40
30
20
10
0
TEMPERATURE
AVERAGE 67°
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

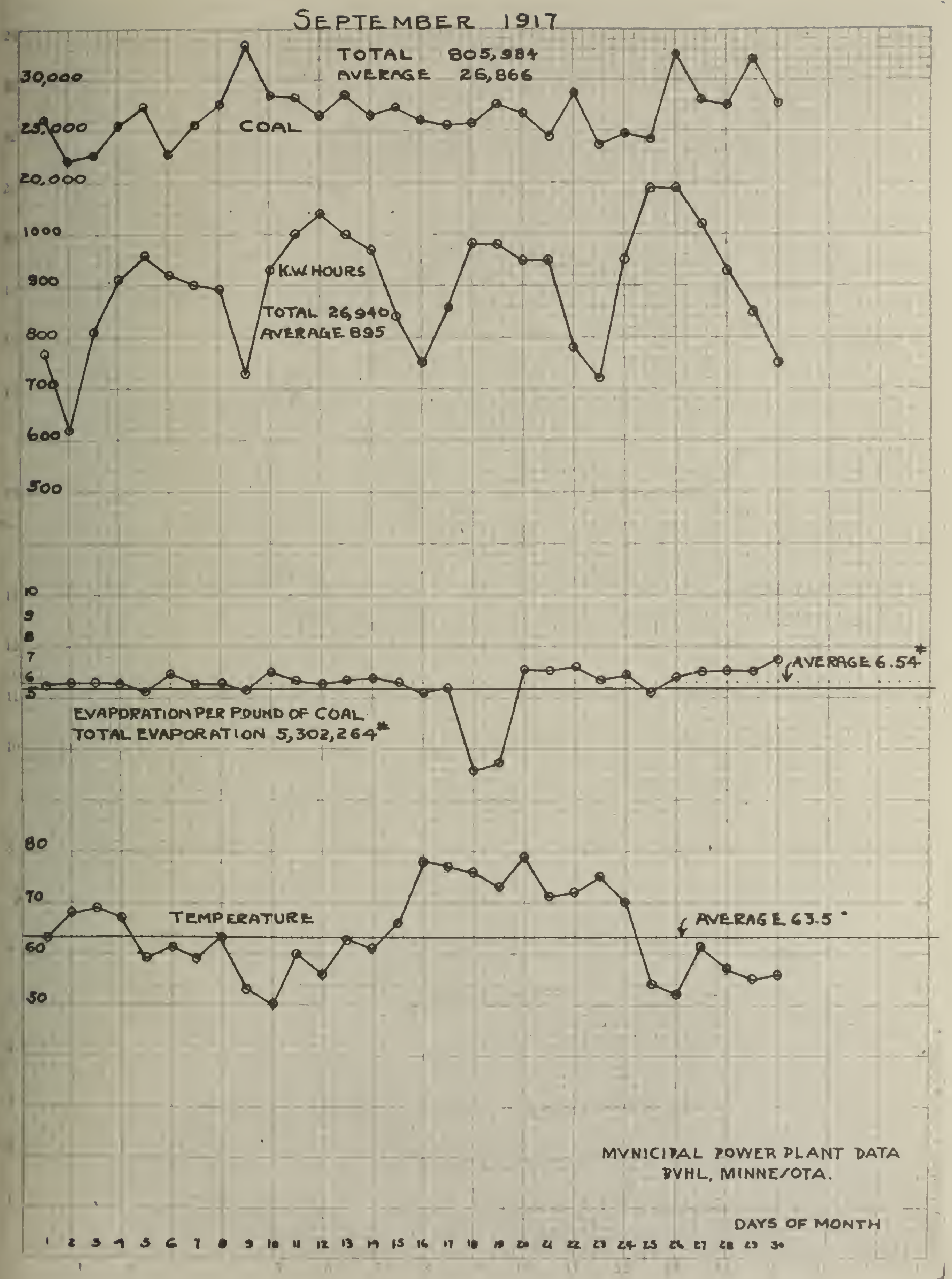

JUNE 1917.
HORSE POWER RATING OF BOILERS IN OPERATION
AVERAGE 301.5
300
250
200
150
100
BOILER
HORSE POWER
DEVELOPED
80
70
60
50
40
30
AVERAGE 69.7%
PERCENT OF
BOILER RATING
DEVELOPED
DAYS OF MONTH
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
EVAPOR. PER POUND OF COAL
6
5
4
3
2
1
0
10 20 30 40 50 60 70 80 90 100 110 120 130
% RATING
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA

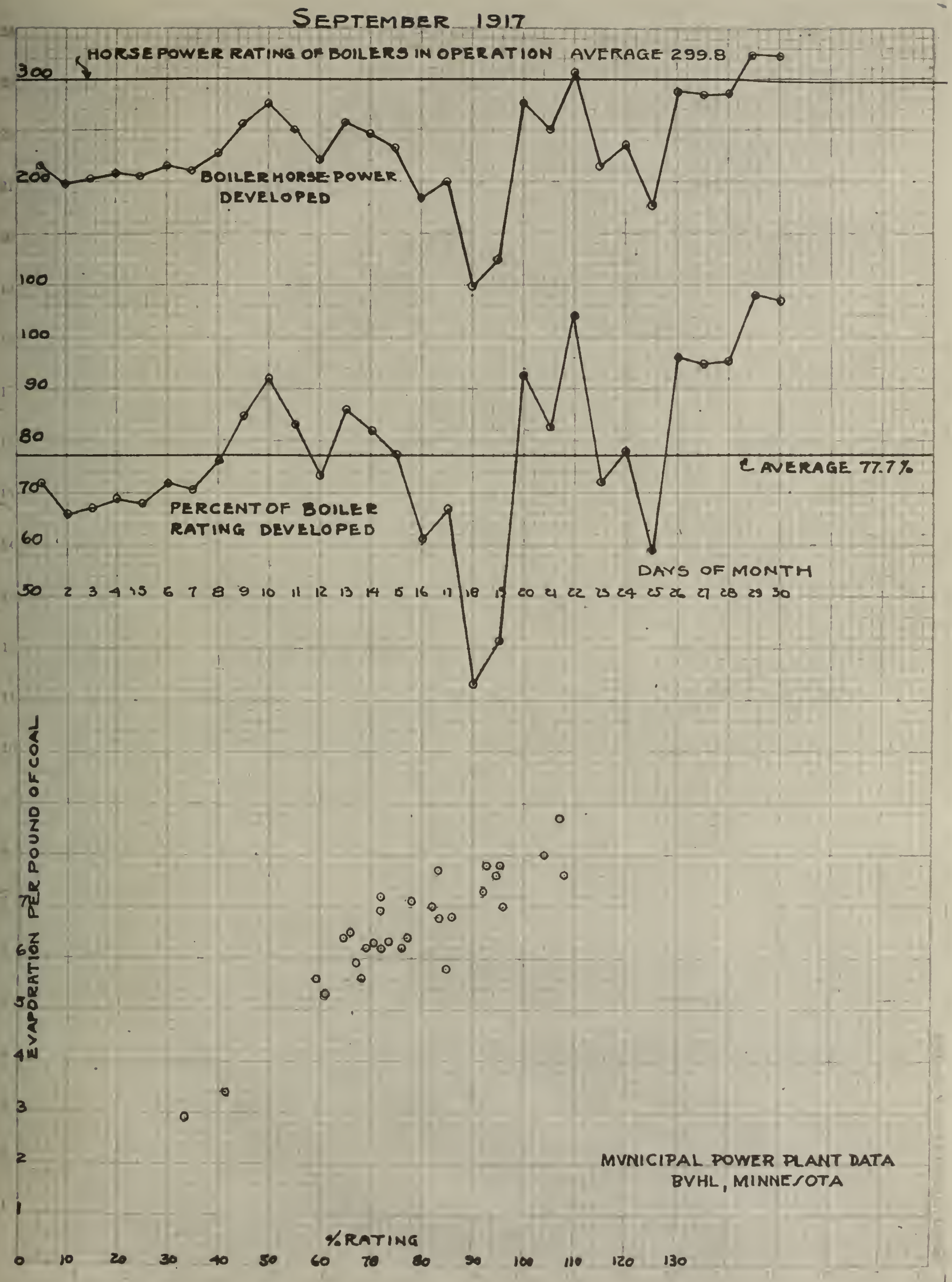

JULY 1917
30000
25000
20000
15000
COAL
TOTAL 688,779#
AVERAGE 22,219#
800
700
600
500
K.W. HOURS
TOTAL 20,460
AVERAGE 660
10
9
8
7
6
5
4
3
EVAPORATION PER POUND OF COAL
AVERAGE 6.4#
TOTAL EVAPORATION 4,266,960#
80
70
60
50
40
30
20
10
0
TEMPERATURE
AVERAGE 79°
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

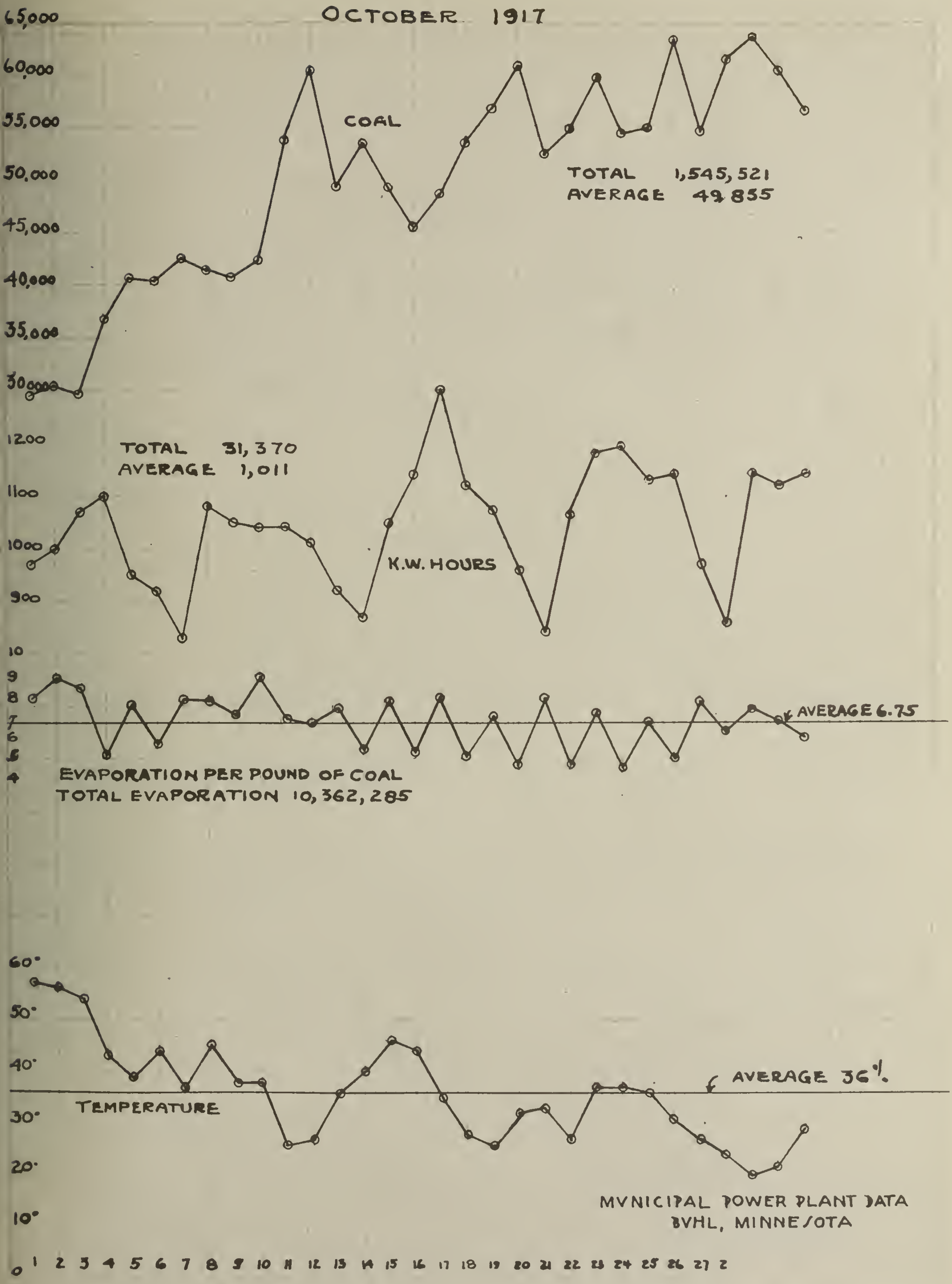

JULY 1917
HORSE POWER RATING OF BOILERS IN OPERATION
AVERAGE 299.6
300
250
200
150
100
BOILER HORSE POWER DEVELOPED
90
80
70
60
50
40
30
AVERAGE 63%
PERCENT OF BOILER RATING DEVELOPED
DAYS OF MONTH
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 24 25 26 27 28 29 30
EVAPORATION PER POUND OF COAL
6
5
4
3
2
1
0
10 20 30 40 50 60 70 80 90 100 110 120 130
% RATING
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA

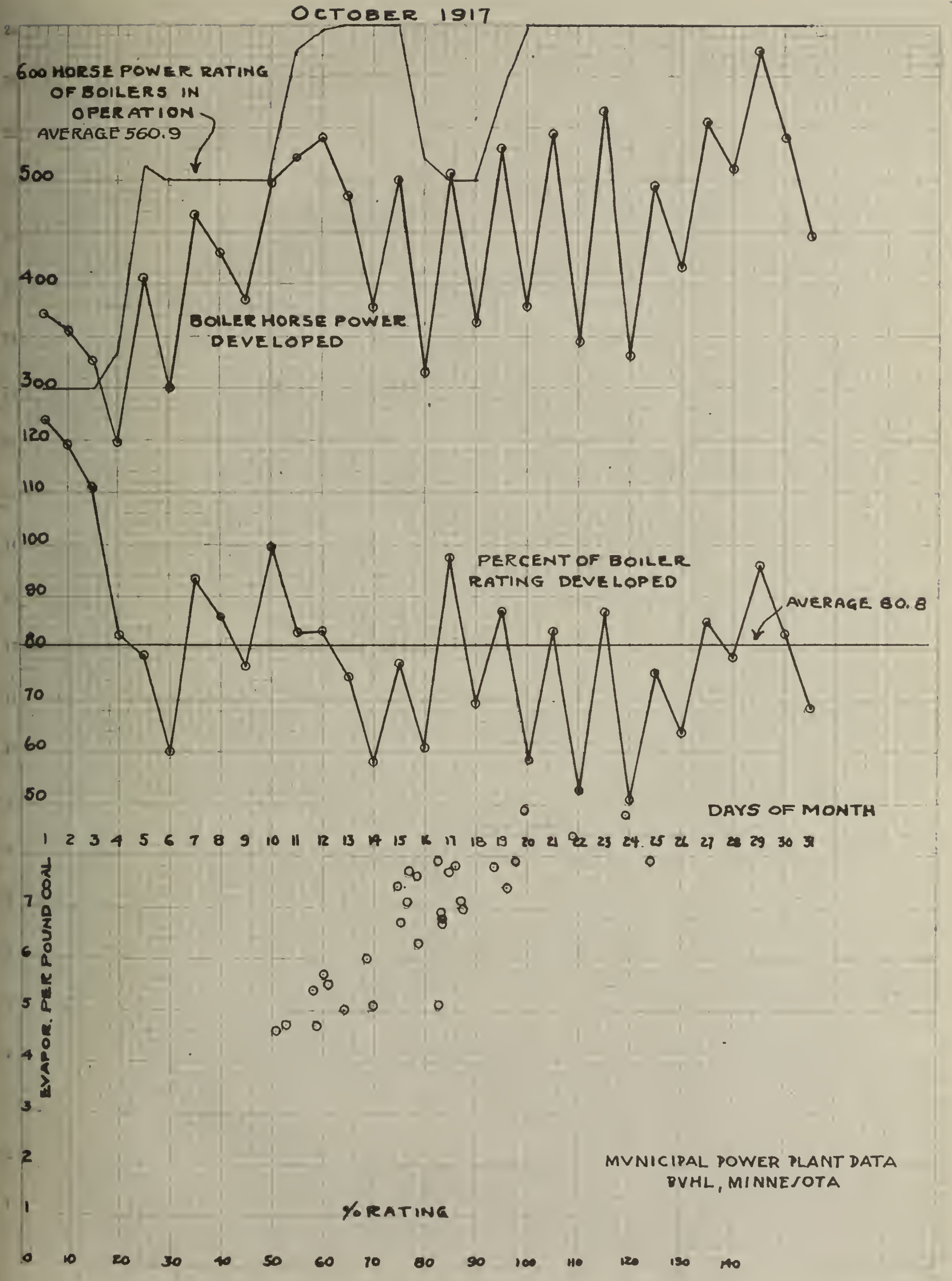

AUGUST 1917
30000
25000
20000
COAL
TOTAL 723,223#
AVERAGE 23,330#
900
800
700
600
500
K.W. HOURS
TOTAL 22,690
AVERAGE 732
10
9
8
7
6
5
EVAPORATION PER POUND OF COAL
TOTAL EVAPORATION 4,359,513#
AVERAGE 6.3
90
80
70
60
50
40
30
20
10
0
TEMPERATURE
AVERAGE 69.1
MUNICIPAL POWER PLANT DATA
DUHL, MINNESOTA
DAYS OF MONTH.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

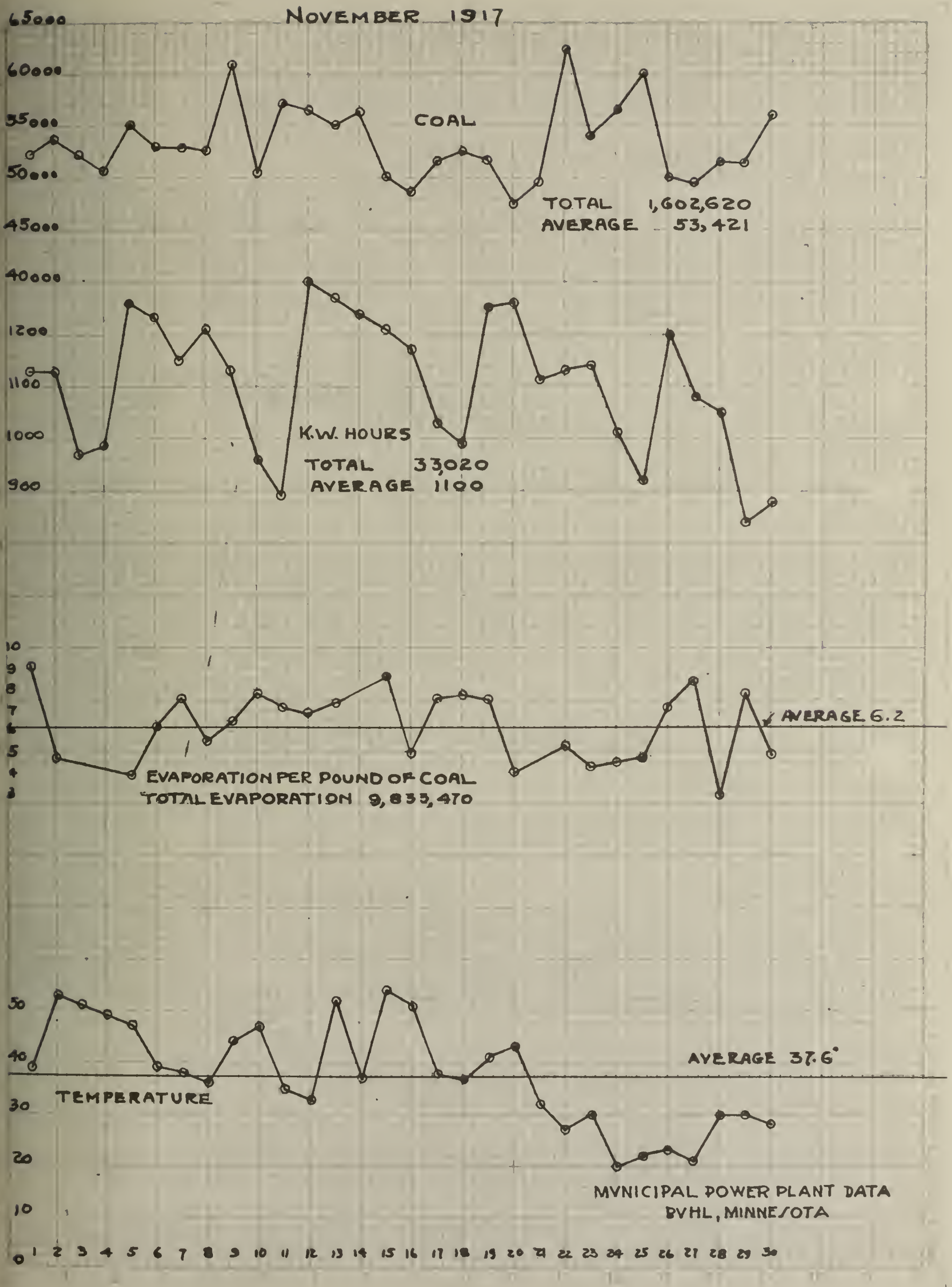

AUGUST 1917
HORSE POWER RATING OF BOILERS IN OPERATION
AVERAGE 301.4
300
200
BOILER HORSE POWER DEVELOPED
100
80
70
AVERAGE 64.2
60
PERCENT OF BOILER RATING DEVELOPED
50
40
DAYS OF MONTH
30
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
20
1.0
EVAPOR. PER POUND OF COAL
5
4
3
2
1
0
10 20 30 40 50 60 70 80 90 100 110 120 130
% RATING
MVNICIPAL POWER PLANT DATA
DVHL, MINNESOTA

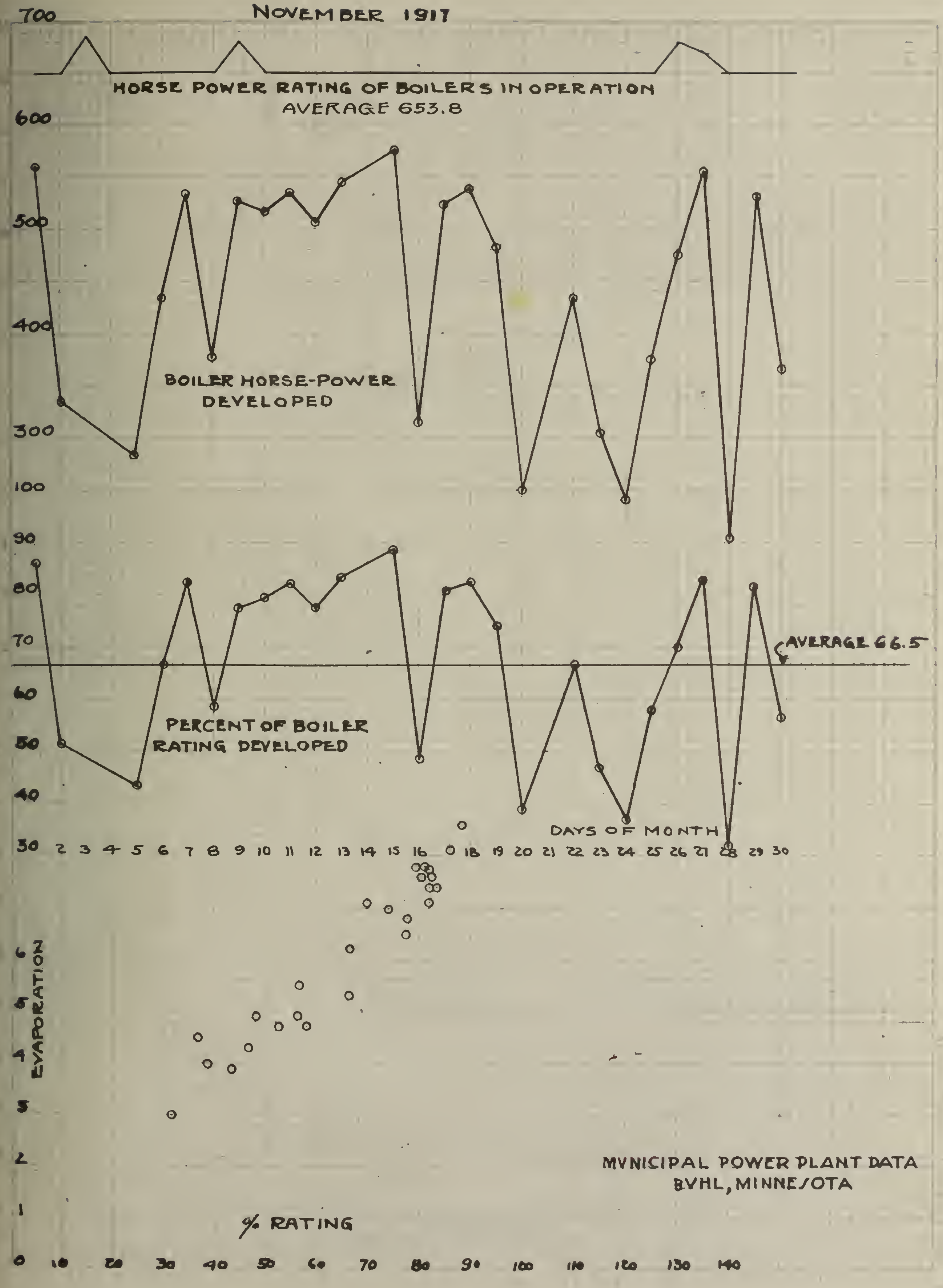

SEPTEMBER 1917
TOTAL 805,984
AVERAGE 26,866
30,000
25,000
20,000
COAL
1000
900
800
700
600
500
K.W. HOURS
TOTAL 26,940
AVERAGE 895
10
9
8
7
6
5
AVERAGE 6.54#
EVAPORATION PER POUND OF COAL
TOTAL EVAPORATION 5,302,264#
80
70
60
50
TEMPERATURE
AVERAGE 63.5°
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA.
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

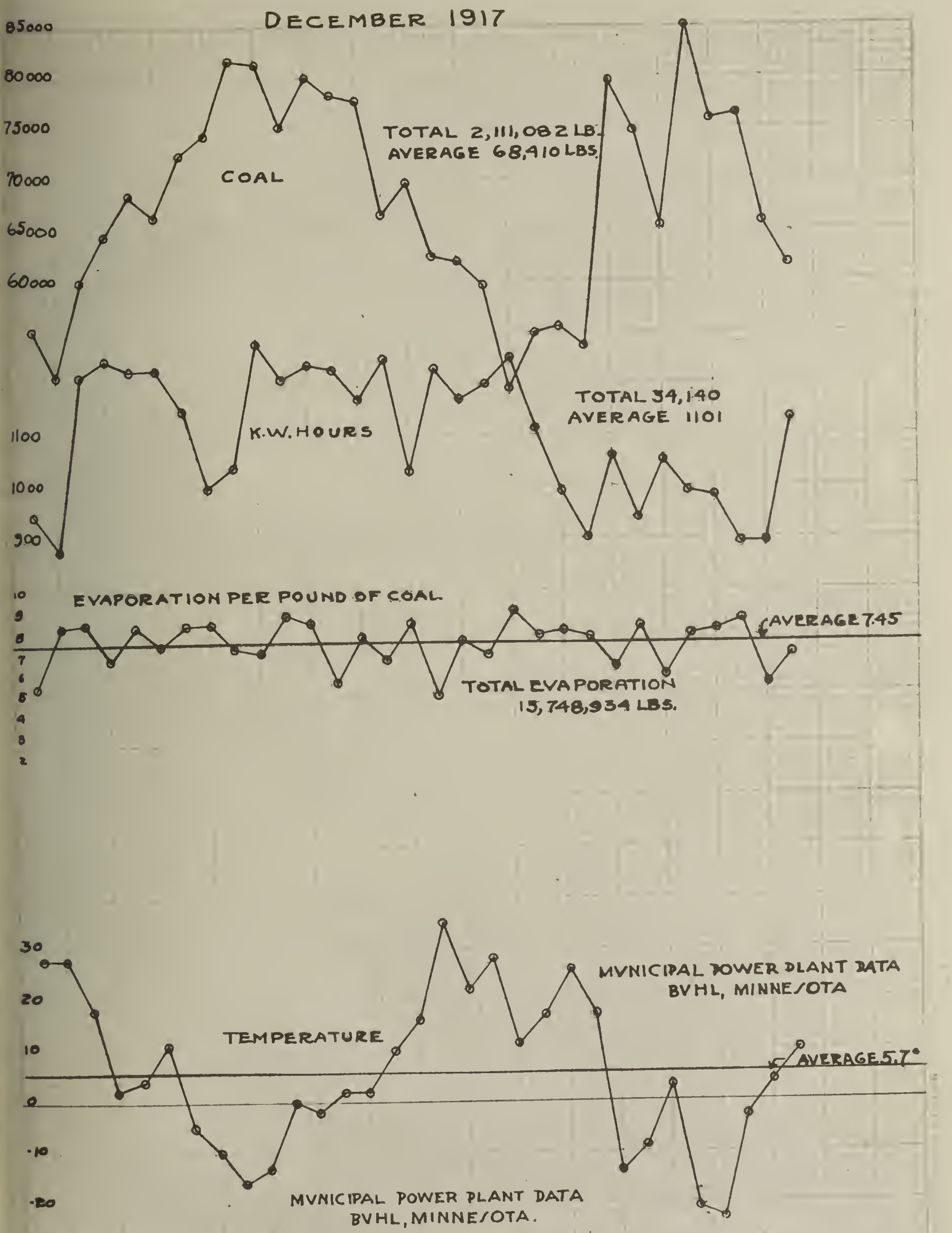

SEPTEMBER 1917
HORSE POWER RATING OF BOILERS IN OPERATION AVERAGE 299.8
300
200
100
BOILER HORSE POWER DEVELOPED
100
90
80
70
60
50
℄ AVERAGE 77.7%
PERCENT OF BOILER RATING DEVELOPED
DAYS OF MONTH
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
EVAPORATION PER POUND OF COAL
1
2
3
4
5
6
7
% RATING
0 10 20 30 40 50 60 70 80 90 100 110 120 130
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA

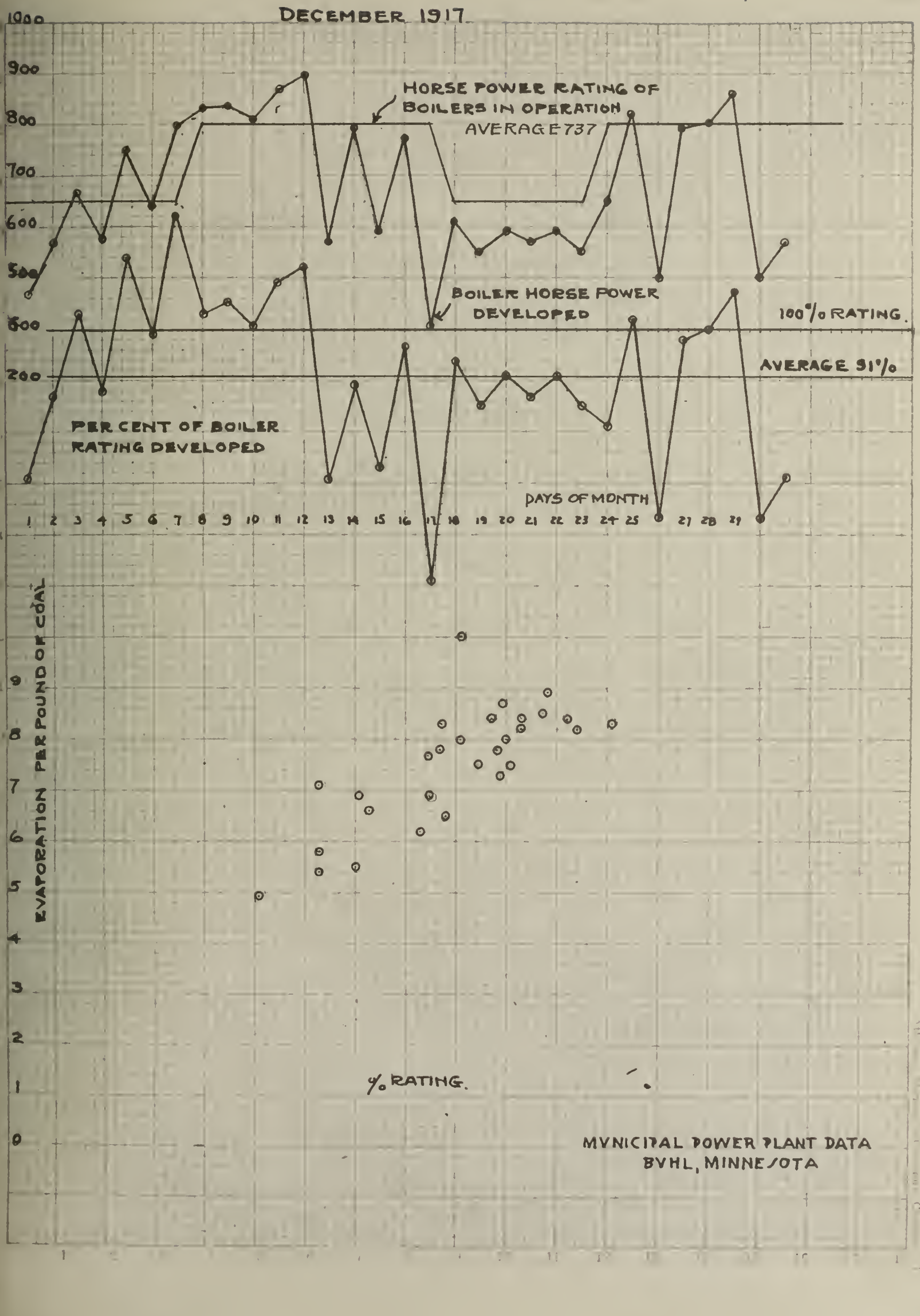

OCTOBER 1917
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
COAL
TOTAL 1,545,521
AVERAGE 49,855
1200
1100
1000
900
TOTAL 31,370
AVERAGE 1,011
K.W. HOURS
10
9
8
7
6
5
4
AVERAGE 6.75
EVAPORATION PER POUND OF COAL
TOTAL EVAPORATION 10,362,285
60°
50°
40°
30°
20°
10°
0
TEMPERATURE
AVERAGE 36%
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 2

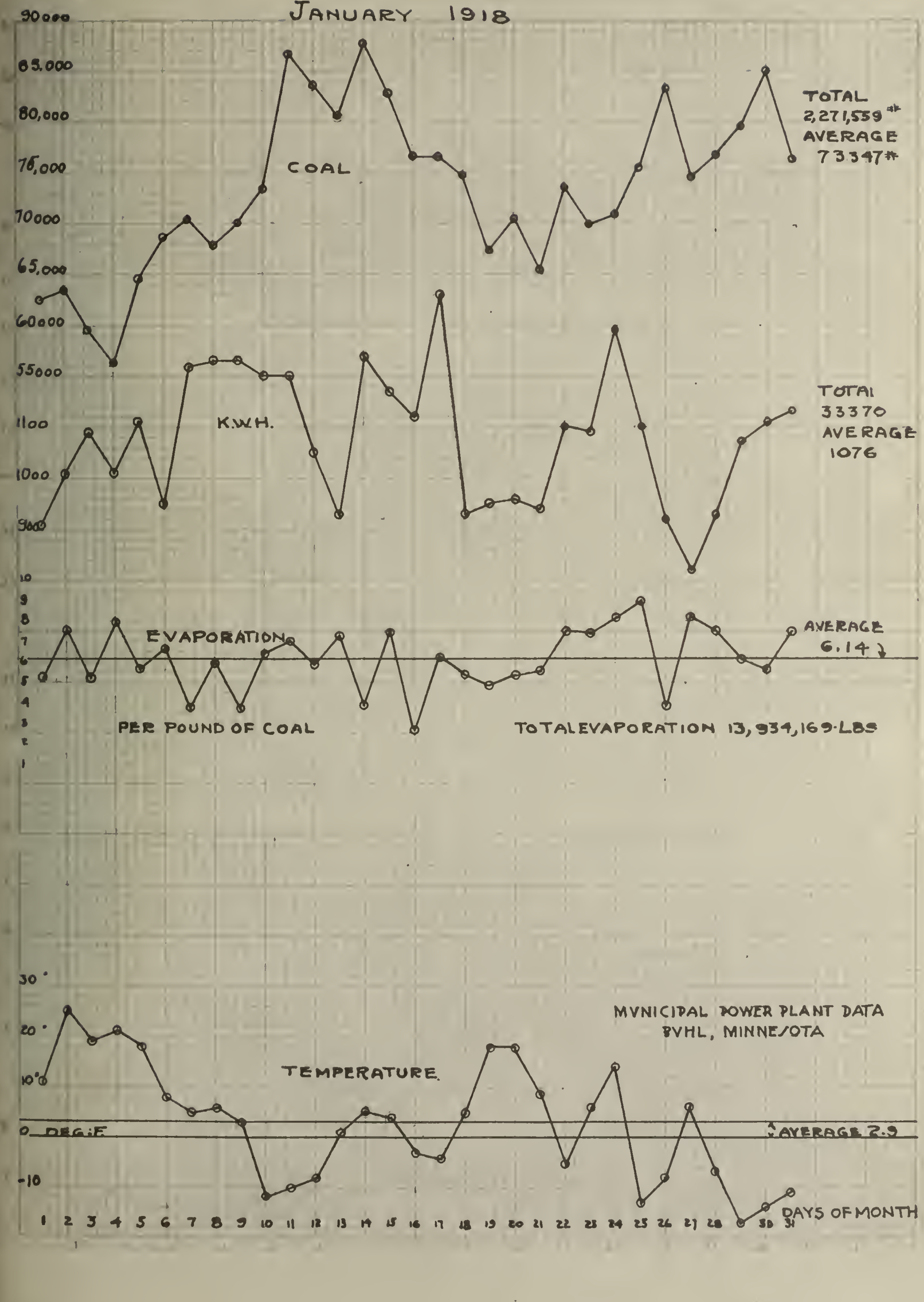

OCTOBER 1917
600 HORSE POWER RATING OF BOILERS IN OPERATION
AVERAGE 560.9
BOILER HORSE POWER DEVELOPED
PERCENT OF BOILER RATING DEVELOPED
AVERAGE 80.8
DAYS OF MONTH
EVAPOR. PER POUND COAL
% RATING
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA
500
400
300
120
110
100
90
80
70
60
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
7
6
5
4
3
2
1
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140

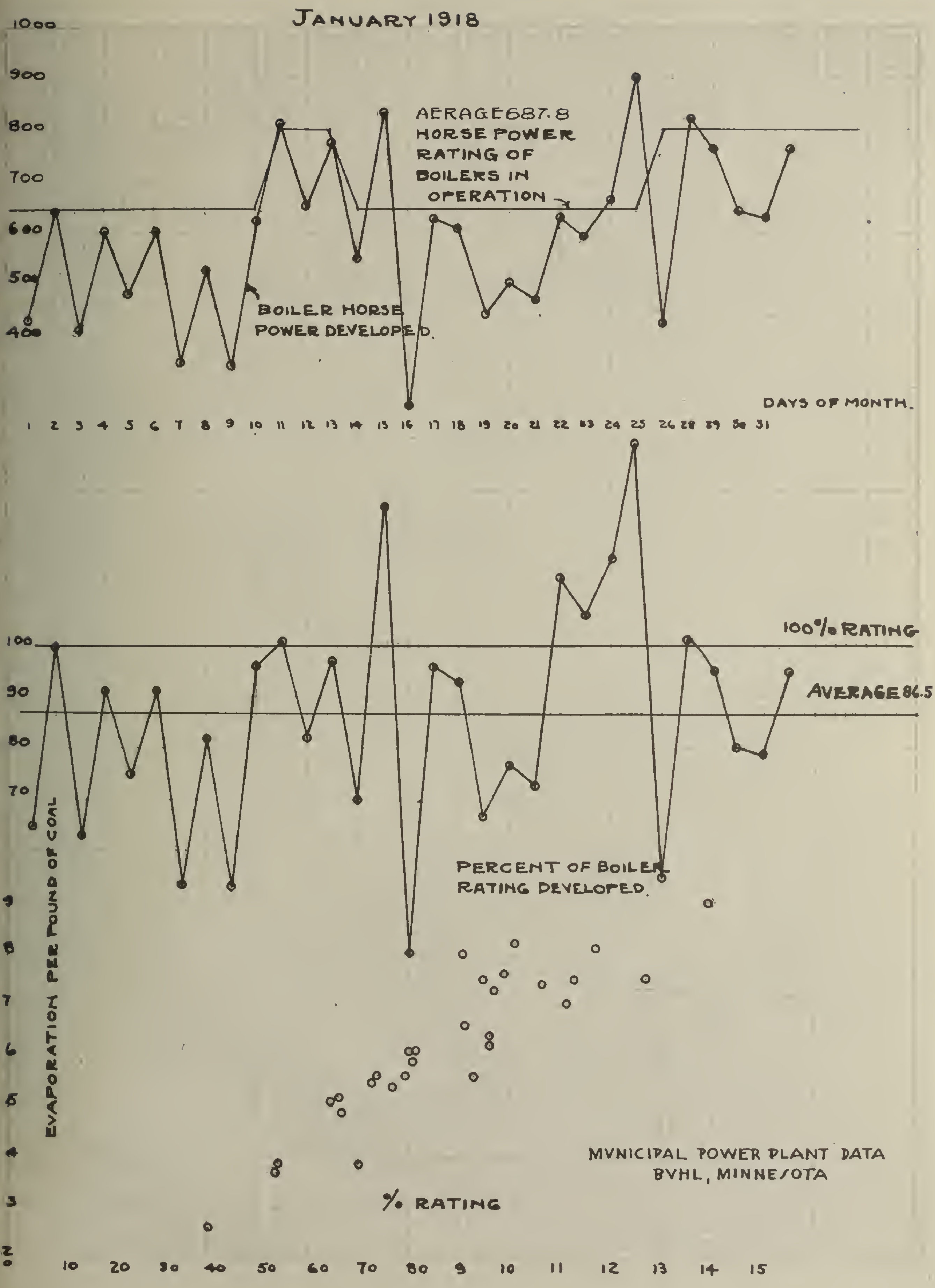

NOVEMBER 1917
65000
60000
55000
50000
45000
40000
1200
1100
1000
900
COAL
TOTAL 1,602,620
AVERAGE 53,421
K.W. HOURS
TOTAL 33,020
AVERAGE 1100
10
9
8
7
6
5
4
3
AVERAGE 6.2
EVAPORATION PER POUND OF COAL
TOTAL EVAPORATION 9,835,470
50
40
30
20
10
0
AVERAGE 37.6°
TEMPERATURE
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

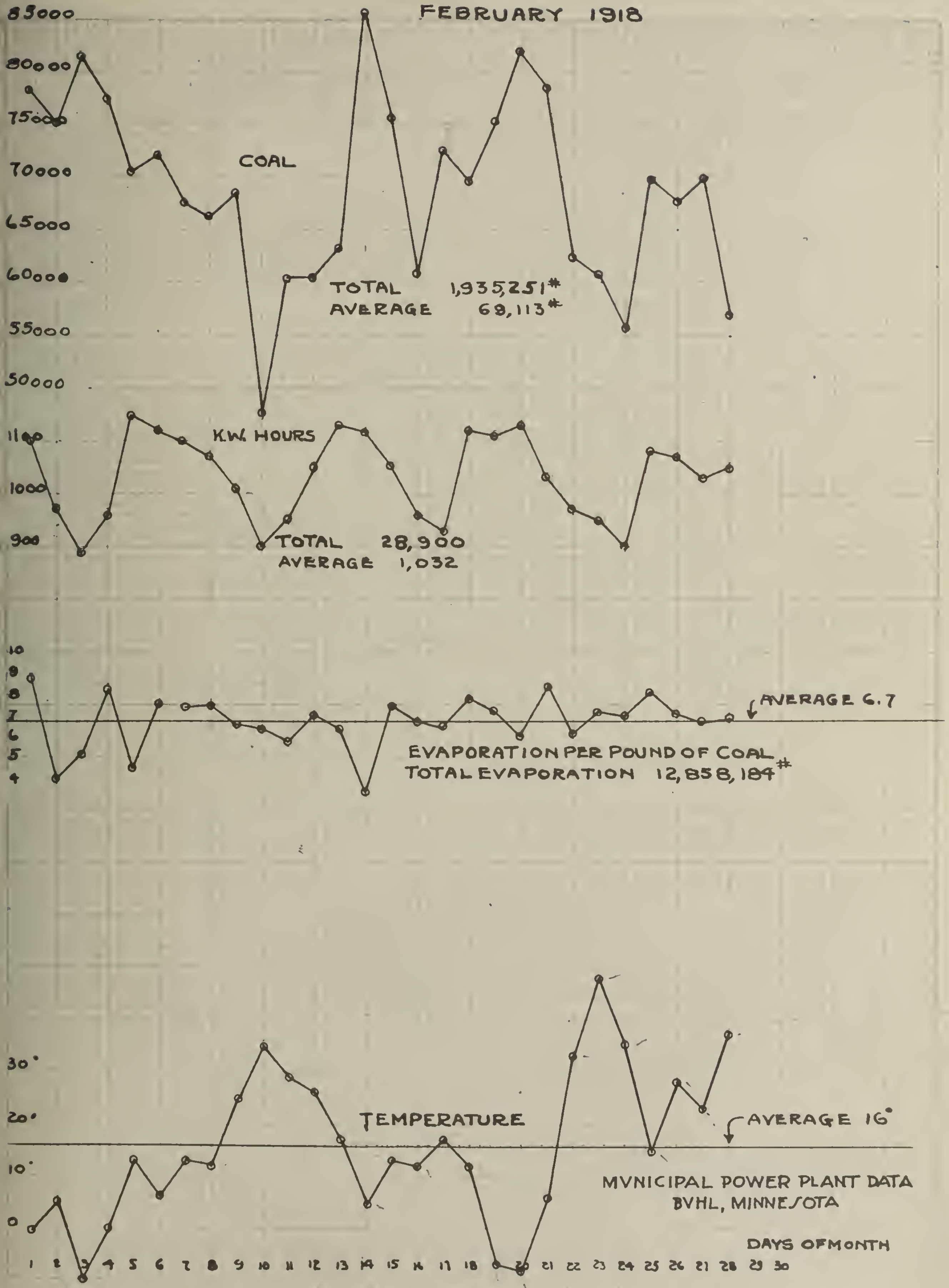

NOVEMBER 1917
700
HORSE POWER RATING OF BOILERS IN OPERATION
AVERAGE 653.8
600
500
400
300
100
90
80
70
60
50
40
30
BOILER HORSE-POWER DEVELOPED
PERCENT OF BOILER RATING DEVELOPED
AVERAGE 66.5
DAYS OF MONTH
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 0 18 19 20 21 22 23 24 25 26 27 28 29 30
EVAPORATION
6
5
4
3
2
1
0
% RATING
10 20 30 40 50 60 70 80 90 100 110 120 130 140
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA

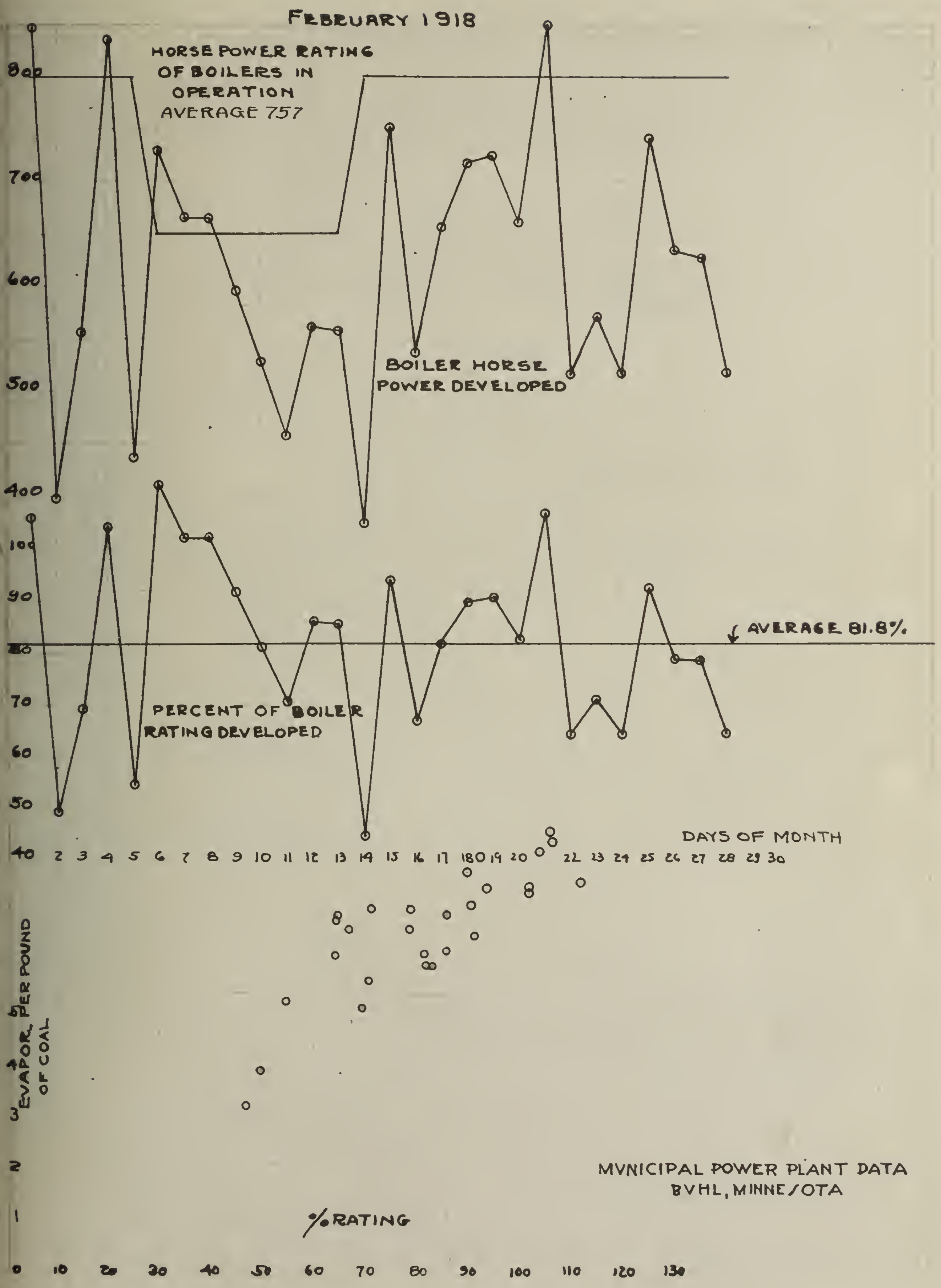

DECEMBER 1917
85000
80000
75000
70000
65000
60000
COAL
TOTAL 2,111,082 LB.
AVERAGE 68,410 LBS.
K.W. HOURS
TOTAL 34,140
AVERAGE 1101
1100
1000
900
10
9
8
7
6
5
4
3
2
EVAPORATION PER POUND OF COAL
AVERAGE 7.45
TOTAL EVAPORATION
15,748,934 LBS.
30
20
10
0
-10
-20
TEMPERATURE
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA
AVERAGE 5.7°
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA.

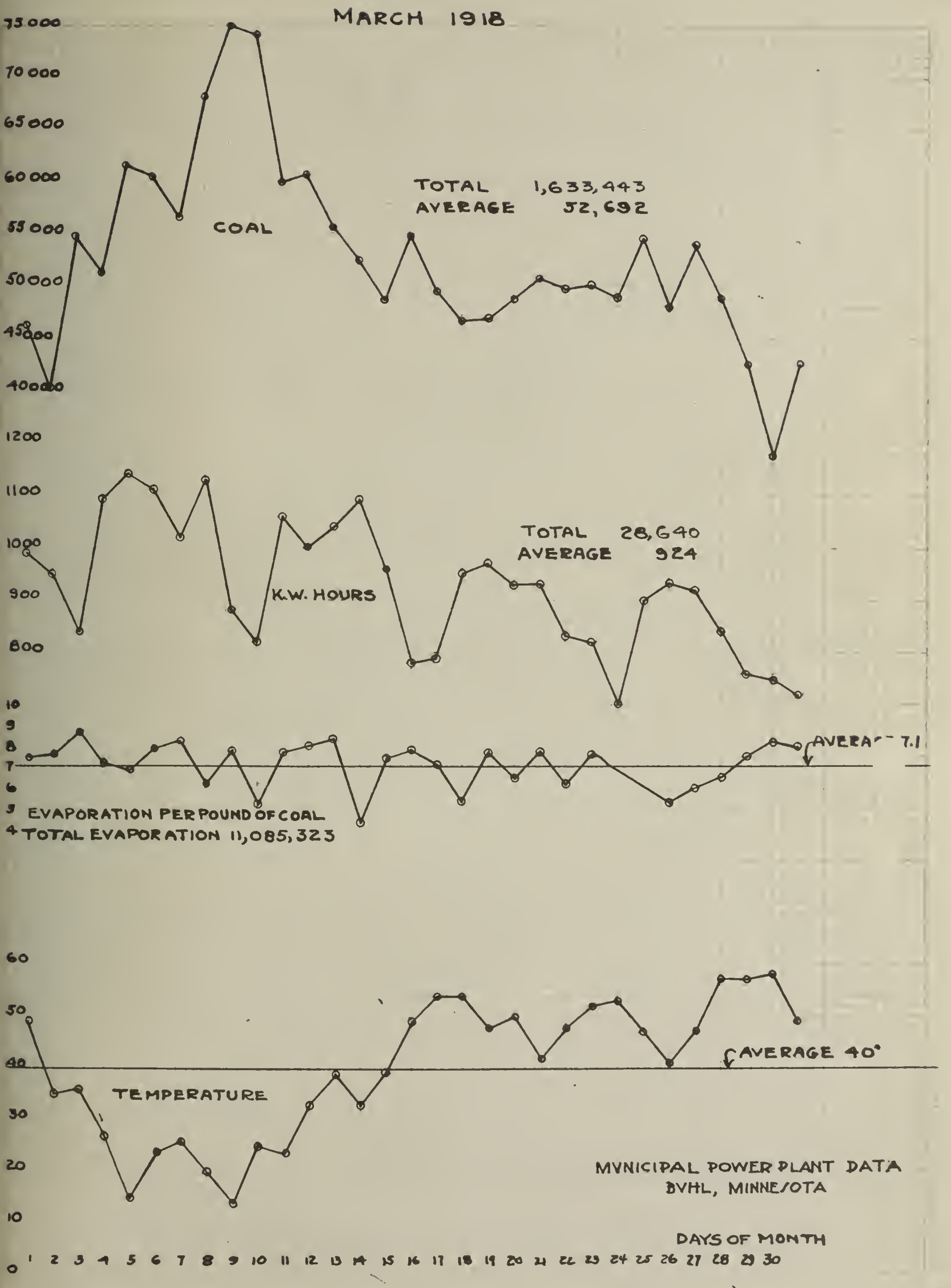

DECEMBER 1917
1000
900
800
700
600
500
600
200
HORSE POWER RATING OF BOILERS IN OPERATION
AVERAGE 737
BOILER HORSE POWER DEVELOPED
100% RATING.
AVERAGE 91%
PER CENT OF BOILER RATING DEVELOPED
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 27 28 29
EVAPORATION PER POUND OF COAL
9
8
7
6
5
4
3
2
1
0
% RATING.
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA

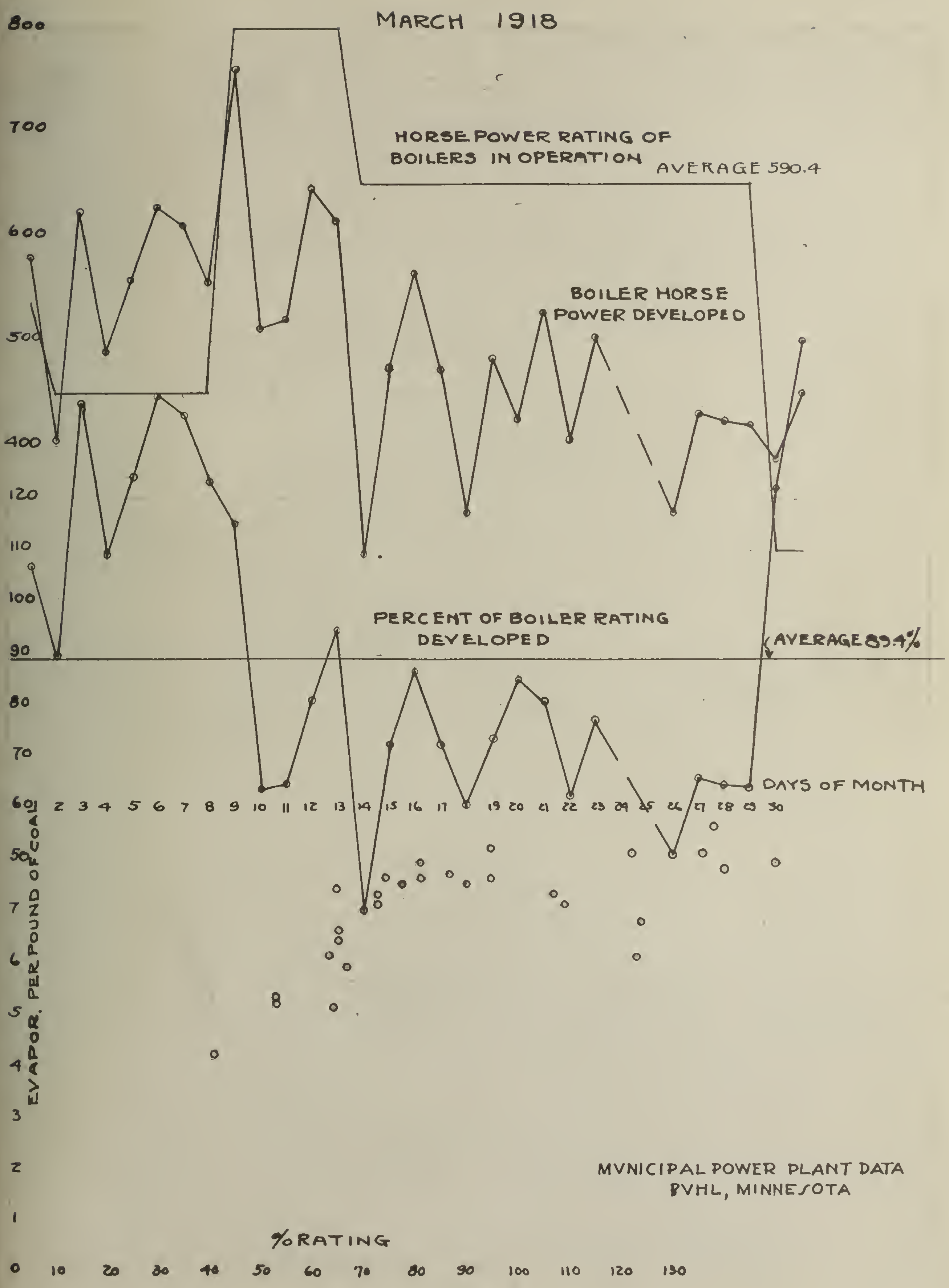

JANUARY 1918
90000
85,000
80,000
75,000
70000
65,000
60000
55000
1100
1000
900
COAL
TOTAL
2,271,559 #
AVERAGE
73347#
K.W.H.
TOTAL
33370
AVERAGE
1076
10
9
8
7
6
5
4
3
2
1
EVAPORATION
AVERAGE
6.14
PER POUND OF COAL
TOTAL EVAPORATION 13,934,169 LBS
30°
20°
10°
0 DEG.F
-10
TEMPERATURE
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA
AVERAGE 2.9
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

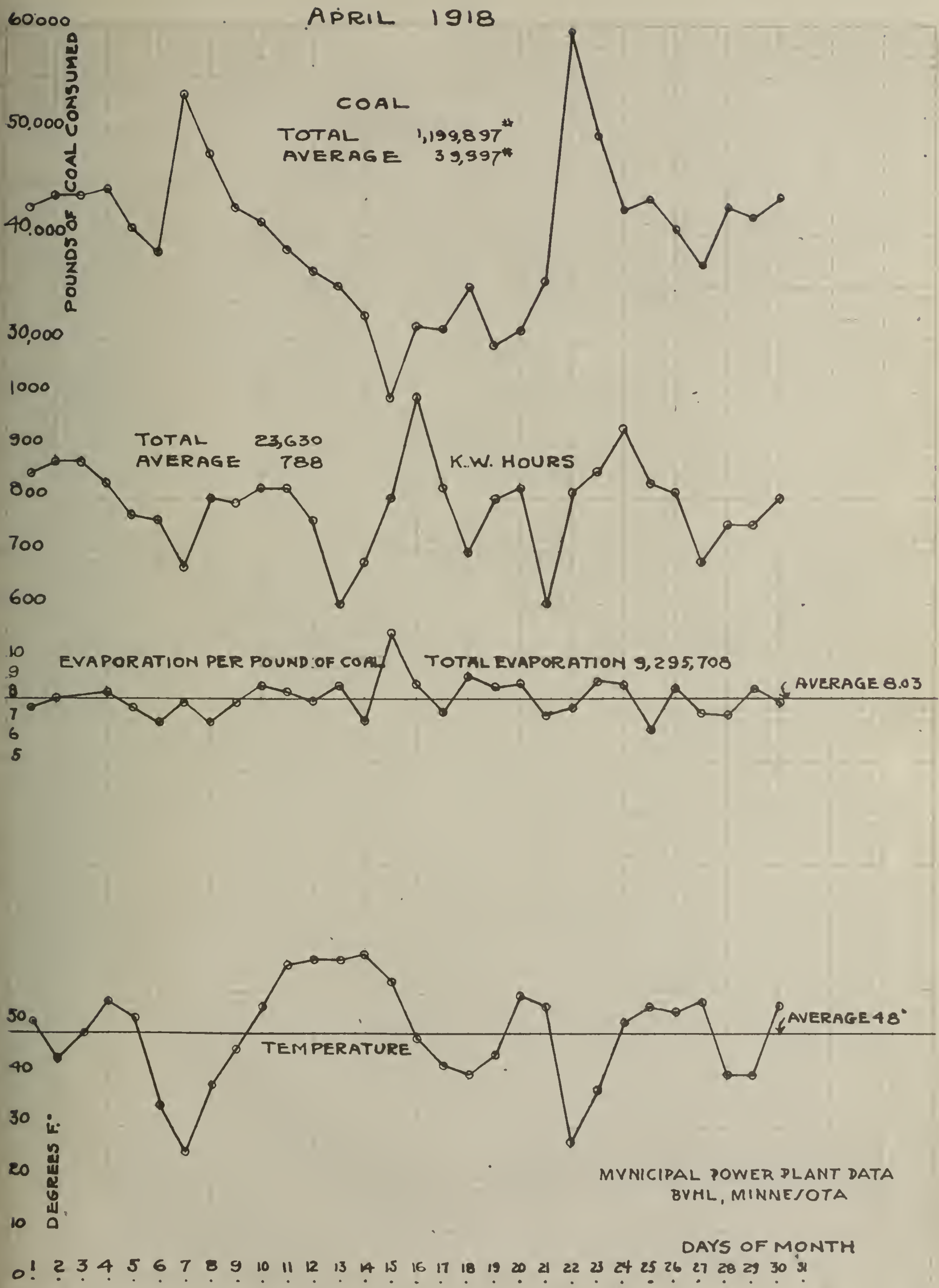

JANUARY 1918
1000
900
800
700
600
500
400
AERAGE 687.8
HORSE POWER
RATING OF
BOILERS IN
OPERATION
BOILER HORSE
POWER DEVELOPED.
DAYS OF MONTH.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 28 29 30 31
100
90
80
70
100% RATING
AVERAGE 86.5
PERCENT OF BOILER
RATING DEVELOPED.
EVAPORATION PER POUND OF COAL
9
8
7
6
5
4
3
2
0
10 20 30 40 50 60 70 80 9 10 11 12 13 14 15
% RATING
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA

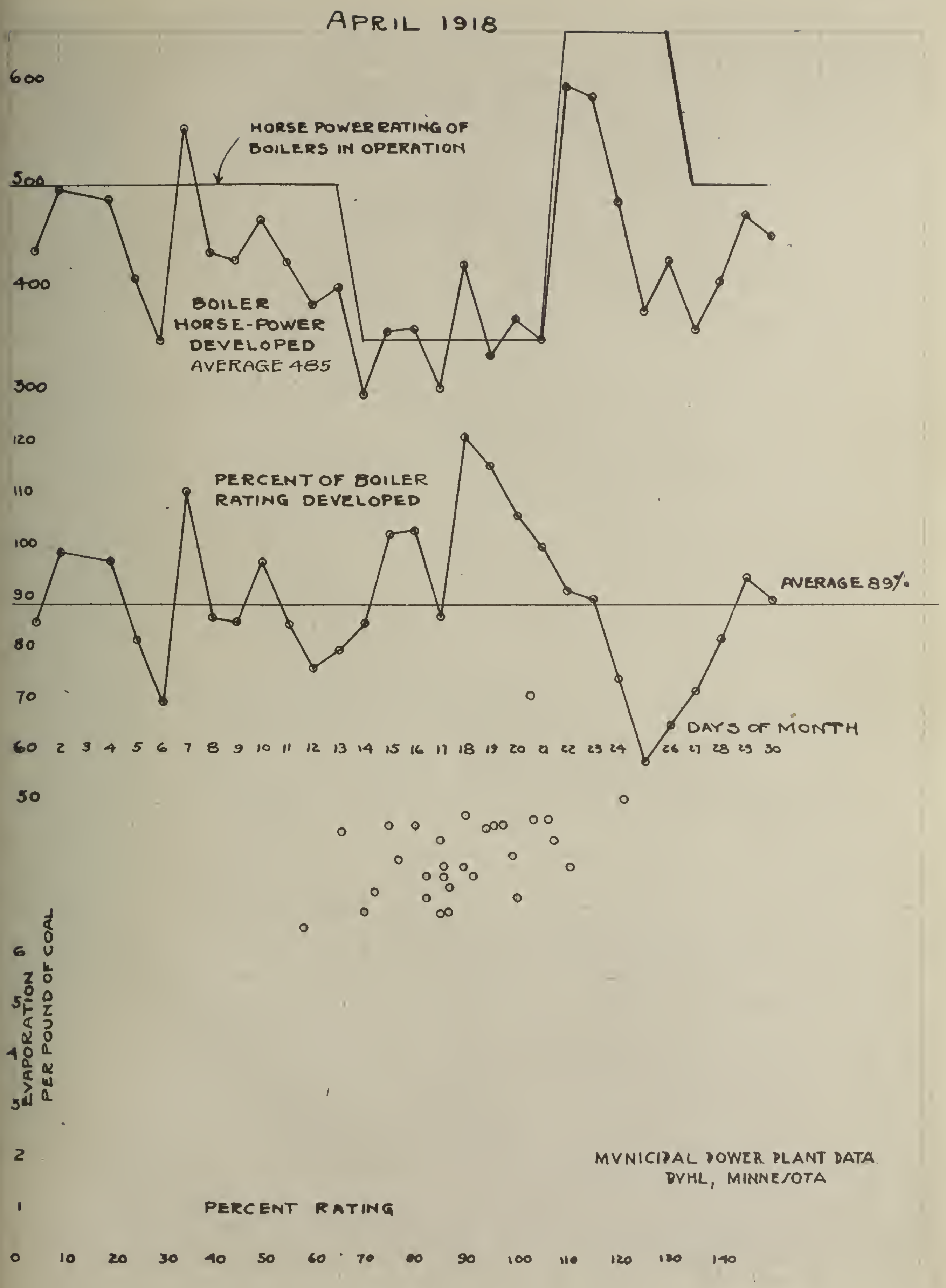

FEBRUARY 1918
85000
80000
75000
70000
65000
60000
55000
50000
COAL
TOTAL 1,935,251#
AVERAGE 69,113#
1100
1000
900
K.W. HOURS
TOTAL 28,900
AVERAGE 1,032
10
9
8
7
6
5
4
AVERAGE 6.7
EVAPORATION PER POUND OF COAL
TOTAL EVAPORATION 12,858,184#
30°
20°
10°
0
TEMPERATURE
AVERAGE 16°
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

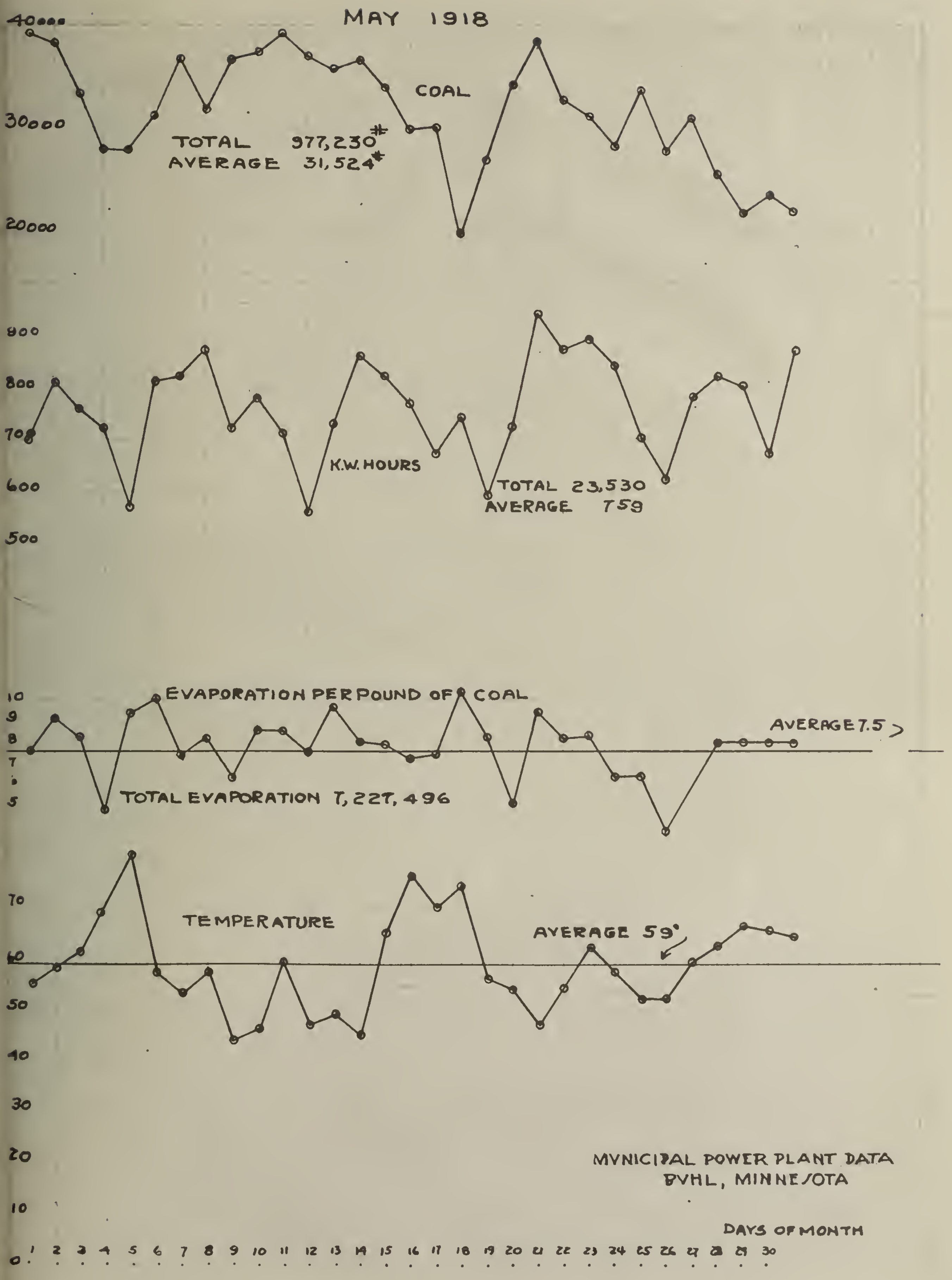

FEBRUARY 1918
HORSE POWER RATING OF BOILERS IN OPERATION AVERAGE 757
BOILER HORSE POWER DEVELOPED
PERCENT OF BOILER RATING DEVELOPED
AVERAGE 81.8%
800
700
600
500
400
100
90
80
70
60
50
40
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
DAYS OF MONTH
EVAPOR. PER POUND OF COAL
5
4
3
2
1
0
%RATING
10 20 30 40 50 60 70 80 90 100 110 120 130
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA

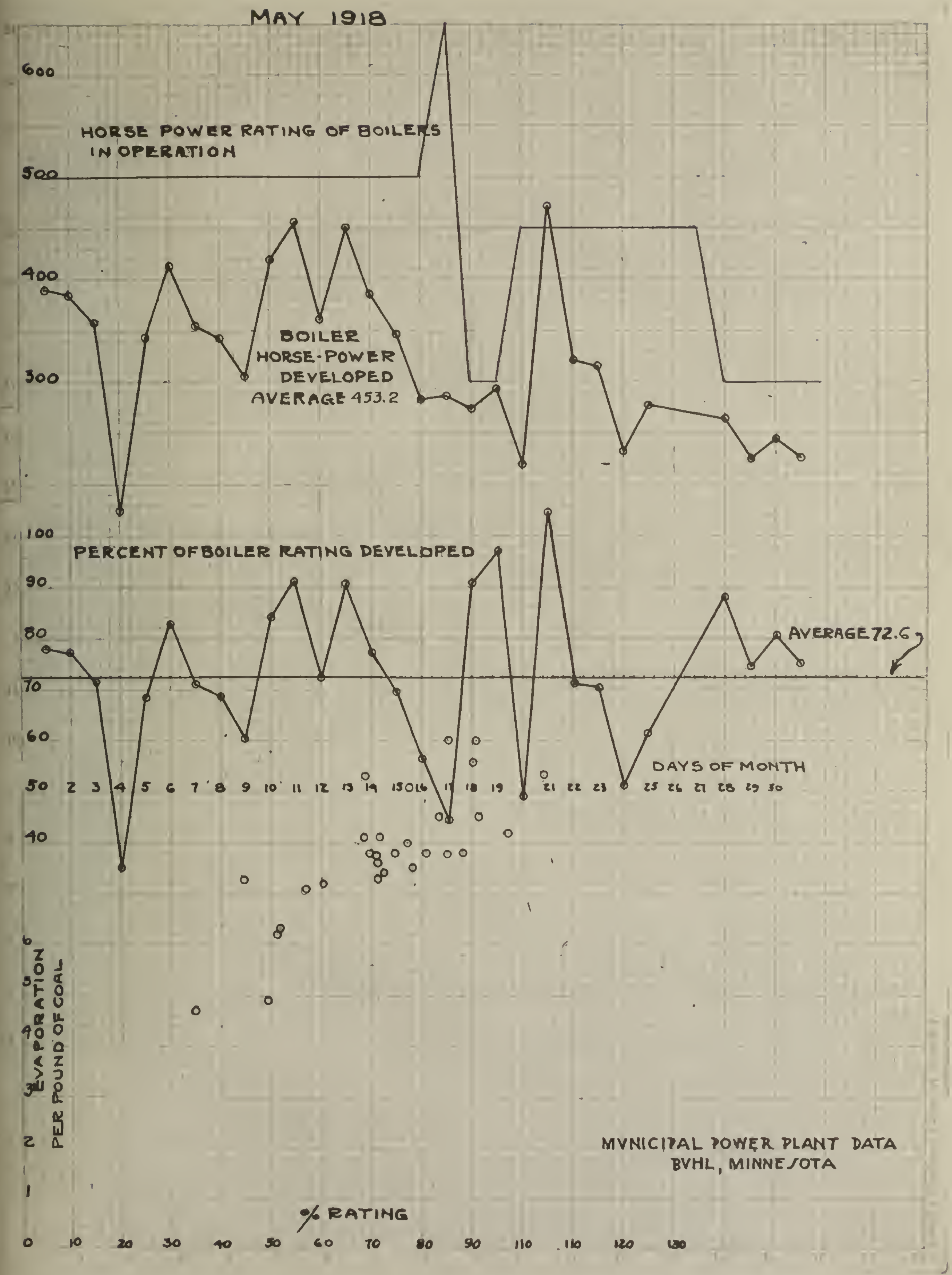

MARCH 1918
75 000
70 000
65 000
60 000
55 000
50000
45000
40000
COAL
TOTAL 1,633,443
AVERAGE 52,692
1200
1100
1000
900
800
K.W. HOURS
TOTAL 28,640
AVERAGE 924
10
9
8
7
6
5
4
AVERA 7.1
EVAPORATION PER POUND OF COAL
TOTAL EVAPORATION 11,085,323
60
50
40
30
20
10
0
TEMPERATURE
AVERAGE 40°
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


MARCH 1918
HORSE POWER RATING OF BOILERS IN OPERATION
AVERAGE 590.4
BOILER HORSE POWER DEVELOPED
PERCENT OF BOILER RATING DEVELOPED
AVERAGE 89.4%
DAYS OF MONTH
EVAPOR. PER POUND OF COAL
%RATING
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA
800
700
600
500
400
120
110
100
90
80
70
60
50
7
6
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 19 20 21 22 23 24 25 26 27 28 29 30
10 20 30 40 50 60 70 80 90 100 110 120 130


APRIL 1918
60000
50,000
40,000
30,000
POUNDS OF COAL CONSUMED
COAL
TOTAL 1,199,897#
AVERAGE 39,997#
1000
900
800
700
600
TOTAL 23,630
AVERAGE 788
K.W. HOURS
10
9
8
7
6
5
EVAPORATION PER POUND OF COAL
TOTAL EVAPORATION 9,295,708
AVERAGE 8.03
50
40
30
20
10
0
DEGREES F°
TEMPERATURE
AVERAGE 48°
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


APRIL 1918
600
500
400
300
HORSE POWER RATING OF BOILERS IN OPERATION
BOILER HORSE-POWER DEVELOPED AVERAGE 485
120
110
100
90
80
70
60
PERCENT OF BOILER RATING DEVELOPED
AVERAGE 89%
DAYS OF MONTH
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 26 27 28 29 30
50
6
5
4
3
2
1
0
EVAPORATION PER POUND OF COAL
PERCENT RATING
10 20 30 40 50 60 70 80 90 100 110 120 130 140
MVNICIPAL POWER PLANT DATA
DVHL, MINNESOTA


MAY 1918
40000
30000
20000
COAL
TOTAL 977,230#
AVERAGE 31,524#
900
800
700
600
500
K.W. HOURS
TOTAL 23,530
AVERAGE 759
10
9
8
7
6
5
EVAPORATION PER POUND OF COAL
AVERAGE 7.5
TOTAL EVAPORATION 7,227,496
70
60
50
40
30
20
10
0
TEMPERATURE
AVERAGE 59°
MVNICIPAL POWER PLANT DATA
BVHL, MINNESOTA
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


MAY 1918
600
500
400
300
100
90
80
70
60
50
40
HORSE POWER RATING OF BOILERS IN OPERATION
BOILER HORSE-POWER DEVELOPED AVERAGE 453.2
PERCENT OF BOILER RATING DEVELOPED
AVERAGE 72.6
DAYS OF MONTH
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 21 22 23 25 26 27 28 29 30
6
5
4
3
2
1
EVAPORATION PER POUND OF COAL
MUNICIPAL POWER PLANT DATA
BUHL, MINNESOTA
% RATING
0 10 20 30 40 50 60 70 80 90 110 110 120 130

Form No 13

# VILLAGE OF BUHL, MINNESOTA

Charles L. Pillsbury Co. POWER STATION RECORD DATE 19

| Time | BOILERS | | | | TEMPERATURES | | | | DRAFT | | Co² | Power Factor | GENERATORS | | | | | | | FEEDERS | | | | HOURS OF OPERATION | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In Service | | | | Outside | Vac. Return | Boiler Feed | Flue Gas | Fur. | Upt. | % | | No. 1 Unit-75 K. W. | | | No. 2 Unit-250 K. W. | | | Volts | Comm | Orn'tl | Pump | Series | Air Comp | | Pumps | | Orn'tl Ltg. | | Series St. Ltg. | |
| | 1 | 2 | 3 | 4 | | | | | | | | | Amps. A | Amps. B | Amps. C | Amps. A | Amps. B | Amps. C | | Amps | Amps | Amps | Amps | Start | Stop | Start | Stop | On | Off | On | Off |
| Noon 12.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12.00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Average | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| Read | DAILY ELECTRIC METER READINGS | | | | | DAILY WATER METER READINGS | | | | DAILY COAL CONSUMPTION | | | | COAL RECEIVED DAILY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noon | Commercial | Ornamental | K. W. HOURS | | Total | City Flow Meter | | B. F. Water-Weigher | | Kind of Coal | Total Pounds | Water Per Lb. Coal | Total Refuse | Kind of Coal | Total Pounds |
| | | | Pumps | Series St. Ltg. | | Reading | Gallons | Reading | Pounds | | | | | | |
| Former | | | | | | | | | | | | | | | |
| Present | | | | | | | | | | | | | | | |
| Diff. or Total | | | | | | | | | | | | | | | |

REMARKS:

Minneapolis
November 16
1918.

The Village Water, Light, Power & Heat Board,

Buhl, Minnesota.

Gentlemen:-

In accordance with our agreement, our Mr. Craig made an inspection of your municipal plant on November 4th last. We have also received the records of your plant for the month of October 1918.

The following tabulation shows the comparative operation of the plant during the months of October 1917 and October 1918:

| | October 1917. | October 1918. |
|---|---|---|
| Total pounds of coal consumed, | 1,545,521 | 1,149,548 |
| Outside Temperature, degrees F. | 36 | 45.6 |
| Horse power rating of boilers in operation | 560.9 | 372.7 |
| Pounds of coal per sq.ft. grate surface per hour | 15.4 | 17.2 |

The above tabulation is taken from your records, and indicates that for October this year your coal consumption was reduced 198 tons as compared to the corresponding period the previous year, or a saving equivalent to $1,425.00. The temperature, of course, averaged higher during October of this year, but the increase in radiation served would offset that. For the corresponding periods you have reduced your rated boiler horse power in operation from 560.9 to 372.7, or 33.5%. This is due to both decrease in amount of fuel consumed and increase in combustion rate. Your combustion rate increased from 15.4 pounds of coal per square foot of grate surface per hour to 17.2 pounds, or about 12 percent. This increase in combustion is in line with our previous statement that

too much boiler capacity had been in operation. However, the rate is still too low. The United States Fuel Administration gives the most credit for rates between 20 and 30 pounds per square foot per hour. We would say that with your present draft condition, a rate of about 25 pounds would be most economical, and we would strongly recommend that effort be made to bring up the rate.

We find that our recommendations in regard to changes in dampers and breeching have been acted on and the changes made. As a result, the available draft in the furnaces has been considerably increased. In some cases the draft in the uptakes has been increased to as much as 0.7 inch, while previous to the change about 0.3 inch was the maximum. This increase in available draft will permit the burning of more coal on each grate and consequently increase the load that can be developed in each boiler. Advantage of this increased draft should be taken to increase the load per boiler and reduce the grate surface in operation. This will, of course, make firing somewhat more difficult and will require greater care in management, but will repay for the effort, in economy.

We find that your firemen are taking interest in the use of the draft gauges, in regulating the dampers, and keeping the fires in condition. However, they should give more attention to keeping the fuel beds free from holes. It is to be regretted that they do not have more interested supervision, as they would, without doubt, do wonderfully well if given the proper supervision constantly.

The gas collecting tank should be in operation by now, and regular analyses of the flue gases made. We are presuming that records are being kept of these analyses, as well as of draft and

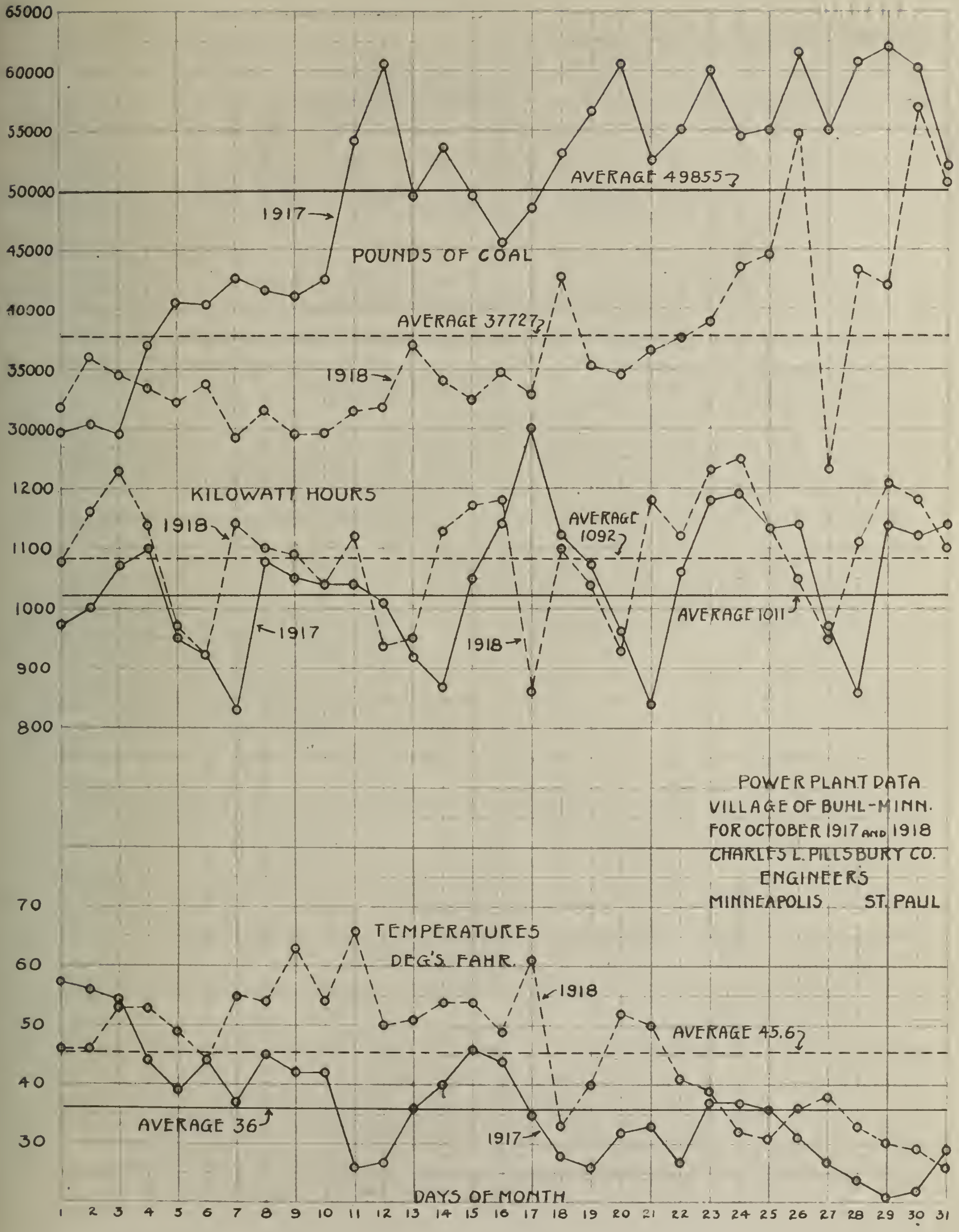
flue temperatures. The results of the analyses should be brought to the attention of the firemen that they may know the results of their work, and try to improve.

Temperature readings in the breeching were taken at the time of inspection. Previous to blowing the flues, the temperature was 530 degrees. Immediately following the blowing of flues, the temperature was 475 degrees, a drop of 55 degrees. This drop in temperature indicates that more heat is taken out of the gases by clean flues than by unclean ones, and consequently less heat lost up the stack. The flues should be blown thoroughly once each shift.

We would recommend that you take immediate steps to provide means for weighing or measuring your feed water, as it seems impossible to make your present weigher operative. Action has been taken to secure priority on your feed water heater, and its delivery and it should be coming through soon.

Results indicate that the plant is operating more efficiently than in the past and we are of the opinion that still better results can be obtained by taking proper action.

Respectfully submitted,
CHARLES L. PILLSBURY CO.
By O.C.



POWER PLANT DATA
VILLAGE OF BUHL-MINN.
FOR OCTOBER 1917 AND 1918
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS ST. PAUL

Minneapolis
December 11
1918.

The Village Water, Light, Power and Heat Board,

Buhl, Minnesota.

Gentlemen:-

In accordance with our contract, an inspection was made of your municipal plant December 4, 1918. We have also received the power plant records for the month of November 1918.

The following tabulation shows the comparative operations of the plant during the months of November 1917 and November 1918.

| | November 1917. | November 1918. |
|---|---|---|
| Total pounds of coal consumed | 1 602 620 | 1 398 512 |
| Outside temperature, degrees F. | 37.5 | 32.6 |
| Average horse power rating of boilers in operation | 653.8 | 450. |
| Pounds of coal per sq.ft. of grate surface per hour | 14.2 | 18. |
| Kilowatt hours per day - average | 1100 | 1100 |

The relative coal consumption, kilowatt hours and outside temperatures for November 1917 and November 1918 are shown on the accompanying curve sheet. The solid lined curves are for November 1917 and the dotted lined curves for November 1918. The data for compiling the table and plotting the curves was taken from your power plant records. It is to be noted that the coal consumption is less by 102 tons for November this year as compared with November last year, altho the temperature was lower and more radiation was served. The average kilowatt hours were practically identical. The rated boiler horse power in operation was decreased from 633.8 to 450, or 31%, due to both decreased consumption and increased rate of combustion. The combustion rate was in-

creased from 14.2 pounds of coal per square foot of grate surface per hour in November 1917 to 18 pounds in November 1918, or by about 27%. The combustion rate was also increased in November 1918 over that in October 1918, by 0.8 pound.

It is to be noted from the curves that there are a number of days in which the fuel consumption was increased altho the temperature remained the same or even rose. In general, with a plant the type of the Buhl plant, the fuel rate should follow the temperature changes rather closely during the heating season, and if the fuel rate rises with a constant or rising temperature, the operation is inefficient. The cause may lie in the fact that the boilers are not as heavily loaded and the furnace efficiency decreased, and there is also a tendency on the part of consumers to open windows and actually use more steam when the weather moderates after a period of cold weather. We believe it would be well worth while for the Board to place a statement in the local paper advising consumers to close radiators when windows are opened.

It is quite possible that more steam will be used during a month in which the temperature is quite variable than during a month in which the temperature is more nearly constant, altho the average temperature may be the same, for the reason as just stated.

It was noted that changes had been made in firemen at the plant. We would like to get information as to the dates that changes were made.

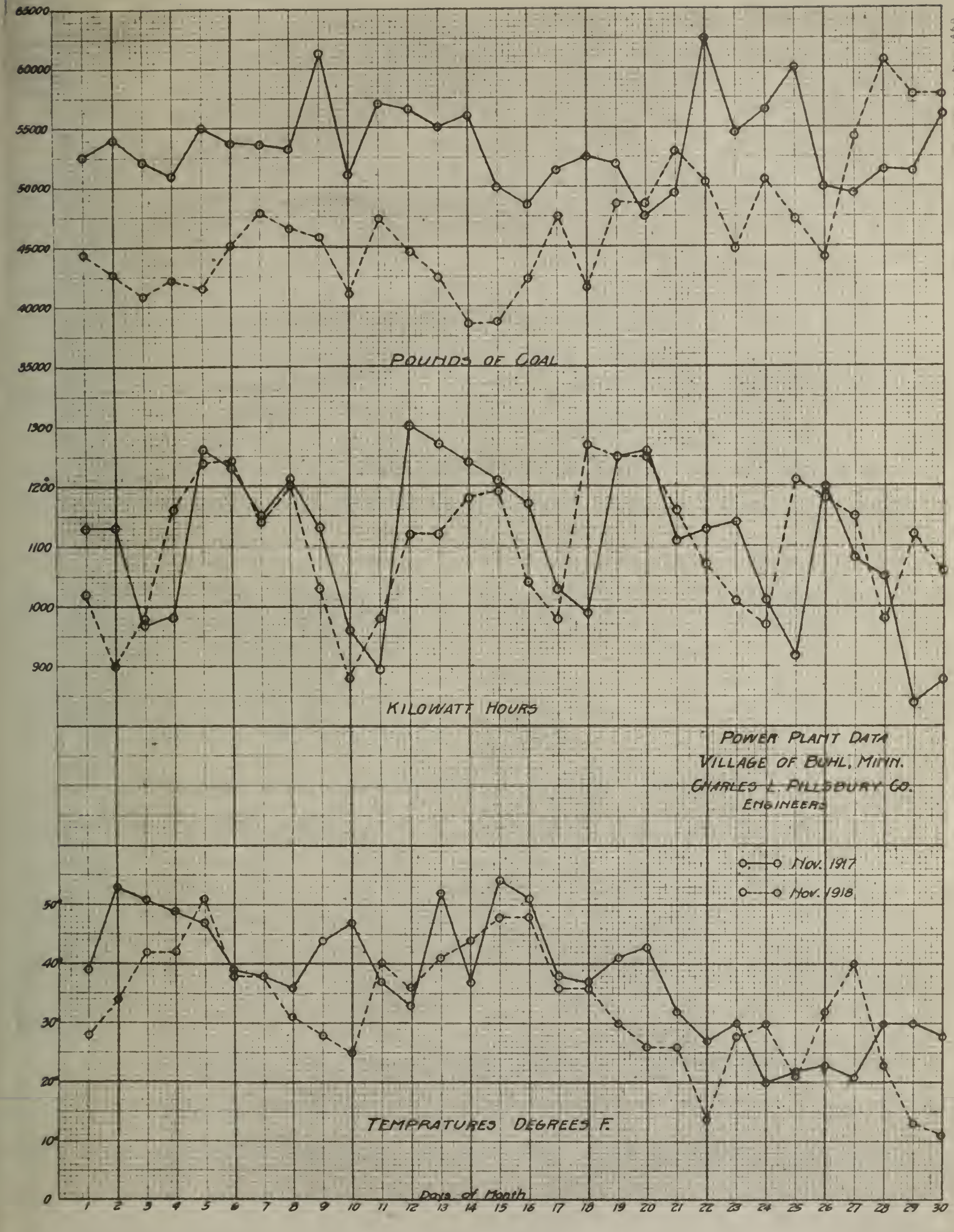
In regard to a feed water heater for the plant, we would strongly recommend that a heater be purchased having a V notch meter in connection. Such a meter can be obtained as a part of

the heater, and a new meter is quite essential to the plant.

Very truly yours,

CHARLES L. PILLSBURY CO.

By O.c.


65000
60000
55000
50000
45000
40000
35000
POUNDS OF COAL
1300
1200
1100
1000
900
KILOWATT HOURS
POWER PLANT DATA
VILLAGE OF BUHL, MINN.
CHARLES L. PILLSBURY CO.
ENGINEERS
Nov. 1917
Nov. 1918
50°
40°
30°
20°
10°
0
TEMPRATURES DEGREES F.
Days of Month
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Minneapolis
January 20
1919.

Village Water, Light, Heat, Power and Building Commission,
Buhl, Minnesota.

Gentlemen:-

In accordance with our contract, an inspection was made of your municipal plant, on January 7th 1919. We have also received the power plant records for the month of December 1918.

The following tabulation shows the comparative operations of the plant during the months of December 1917 and December 1918.

| | December 1917. | December 1918. |
|---|---|---|
| Total pounds of coal consumed | 2,111,082 | 1,618,398 |
| Outside temperature, degrees F. | 5.7 | 23.2 |
| Average horse power rating of boilers in operation | 737 | 497 |
| Pounds of coal per sq.ft. of grate surface per hour | 16 | 18.3 |
| Kilowatt hours per day - average | 1101 | 1100 |

The relative coal consumption, kilowatt hours and outside temperatures for December 1917 and December 1918 are shown on accompanying curve sheet. The solid lines are for December 1917, and the dotted lines for December 1918. The data for compiling the table and plotting the curves was taken from your power plant records.

It is difficult to make a comparison of coal records when there is a radical difference in temperature, as in this case. We might call attention however, to the fact that in 1917, the plant used more coal in November than in October, altho the average temperature was higher. Again, if we compare October 1918 with November 1918, there is indicated a difference of 19,000 pounds of coal

per degree difference of temperature. If we apply that factor to the present case, the coal difference would be 330,000 pounds, based on a temperature difference of 17.5 degrees in December 1918, as compared to December 1917. The actual difference was 492,684 pounds, leaving a net difference of 162,000. Increased radiation served must also be taken into account. There were 5,400 square feet of radiation installed the past season. The records in the Recorder's Office, showed 77,800 square feet in service previous to that - an increase in radiation of about seven percent (7%). If this 7% had been in service under the same conditions as December 1917, the coal consumption for that month would have been 7% greater, or increased by 148,000 pounds.

The total saving for December 1918, as compared to December 1917, can then be conservatively estimated as 162,000 pounds, plus 148,000 or 310,000 pounds or 155 tons. The calculations in connection with increased radiation should also have been applied to October and November reports, but the amount of this radiation was not known to the writer.

The flue gas temperatures varying from 425 degrees Fahrenheit, to 525 degrees Fahrenheit, are very satisfactory.

The feed temperature, averaging 176 degrees is low and should be from 200 degrees to 210 degrees when the new heater is installed.

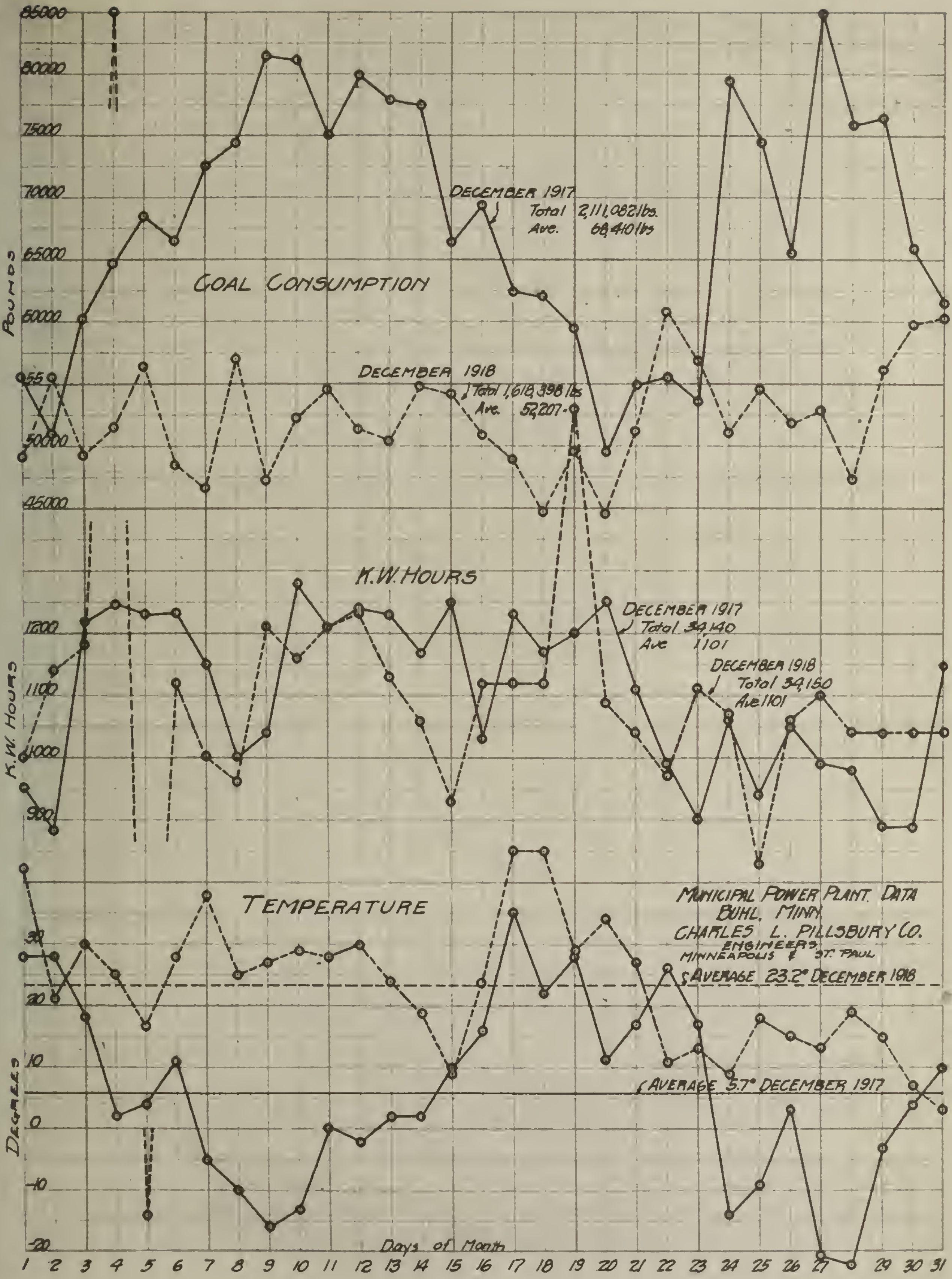
The gas collector should be gotten into operation as soon as possible, and daily analyses of flue gases made.

The chains for changing position of the dampers are not satisfactory, and we would suggest that rods be used in place of chains, and clamps provided to hold them in any set position.

The front doors of the three small boilers should be made to fit closer - to eliminate air leakage.

The writer would be pleased to be advised as to what action has been taken in regard to purchase of heater and meter.

Very truly yours,
CHARLES L. PILLSBURY CO.
By O.C.


85000
80000
75000
70000
65000
60000
55
50000
45000
POUNDS
COAL CONSUMPTION
DECEMBER 1917
Total 2,111,082 lbs.
Ave. 68,410 lbs
DECEMBER 1918
Total 1,618,398 lbs
Ave. 52,207
K.W. HOURS
1200
1100
1000
900
K.W. HOURS
DECEMBER 1917
Total 34,140
Ave 1101
DECEMBER 1918
Total 34,150
Ave 1101
TEMPERATURE
30
20
10
0
-10
-20
DEGREES
MUNICIPAL POWER PLANT DATA
BUHL, MINN.
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS & ST. PAUL
AVERAGE 23.2° DECEMBER 1918
AVERAGE 5.7° DECEMBER 1917
Days of Month
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
29
30
31

Minneapolis
February 15
1919.

Village Water, Light, Heat, Power and Building Commission,
Buhl, Minnesota.

Gentlemen:-

In accordance with our contract, an inspection was made of your municipal plant February 6, 1919. We have also received your power plant records for the month of January 1919, from which the following tabulation was made, together with the records for January 1918.

| | January 1918 | January 1919 |
|---|---|---|
| Total pounds of coal consumed | 2,271,559 | 1,659,350 |
| Outside temperature, degrees F. | 2.9 | 18.1 |
| Average horse power rating of boilers in operation | 687.8 | 538.7 |
| Pounds of coal per sq.ft. of grate surface per hour | 13.7 | 12.8 |
| Kilowatt hours per day - average | 1076 | 1150 |

The relative coal consumption, kilowatt hours, and outside temperatures for January 1918 and January 1919 are shown on accompanying curve sheet. The solid lines are for January 1918 and the dotted lines for January 1919. The data for compiling the table and plotting the curves was taken from your power plant records.

In order to determine a correcting factor for use in cases of difference of temperatures between a given month during the heating season 1917-1918 and the heating season 1918-1919, we have plotted the accompanying curves with total monthly coal consumption in pounds and average monthly outside temperatures in degrees, as coordinates.

The curve for 1918-1919 would indicate a factor of 19,000 pounds per month per degree difference in temperature, while the curve for 1917-1918 would indicate a factor of 14,000 pounds per month per degree difference in temperature. That is, since the plant in 1917-1918 consumed 14,000 pounds more coal per month for each degree drop in average temperature, assuming other factors equal, if the plant had been operating in January of 1919 under the same conditions as it was operating in January 1918, it would have used 14,000 times 15.2 (the temperature difference between the two months) or 212,800 pounds of coal less. This is the amount that should be subtracted from the gross difference in calculating the net difference.

We are using the factor based on last year's operation, rather than the factor based on this year's operation as it is necessary, in order to determine the net saving, to first determine how much less coal would have been consumed if the plant had been operating during January 1919, under the same conditions as January 1918.

The pounds of coal per degree for 1917-1918 is less than the pounds of coal per degree for 1918-1919 since the curve for 1917-1918 is more nearly vertical than the curve for 1918-1919, indicating more efficient and economical utilization in 1918-1919 than in 1917-1918. To explain the reason, if the curve should come vertical, the pounds of coal per degree would be zero, that is, just as much coal would be used each month regardless of the temperature, or in other words, the coal consumption would be just as much in the warmest month as in the coldest month, evidently an extreme case of uneconomical utilization. It is evident, then, that the more

nearly vertical curve represents the more uneconomical utilization.

The fact that the curve for 1918-1919 lies to the left of the curve for 1917-1918 indicates a net total reduction in coal consumption. The fact that the points for 1917-1918 are scattered and do not fall on the average line indicates erratic and inconsistent operation. The fact that the points for 1918-1919 all fall on or very nearly on, the average line indicates consistent operation.

We have made the following calculations and tabulation to indicate the net saving in coal each month this season, since October 1, on the basis of 14,000 pounds per degree difference in temperature, and 7% increase in radiation served:

| | |
|---|---|
| Coal consumed October 1917 . . . . . . . . . . . . . . . | 1 545 521# |
| Coal consumed October 1918 . . . . . . . . . . . . . . . | 1 149 548# |
| Difference . . . . . . . . . . . . . . . . . . . . . . . | 395 973# |
| | |
| Temperature October 1917 . . . . . . . . . . . . . . . | 36° |
| Temperature October 1918 . . . . . . . . . . . . . . . | 45.6° |
| Difference in temperature . . . . . . . . . . . . . . | 9.6° |
| | |
| Correction for increased radiation (.07 x 1 545 521). | 108 186# |
| Correction for difference in temperature (9.6 x 14000) | 134 400# |
| Net saving (395 973 plus 108 186 minus 134 400) . . . | 369 759# |
| | |
| Coal consumption for October 1917 corrected for temperature and radiation conditions of October 1918 (1 545 521 plus 108 186 minus 134 400) . . . . . . . | 1 519 307# |
| Net saving in percent $\frac{369\ 759 \times 100}{1\ 519\ 307}$ | 24.3% |
| Net saving in tons | 184.88 T. |
| Net saving in dollars at $7.50 per ton | $1 385.00 |

| | |
|---|---|
| Coal consumed November 1917 . . . . . . . . . . . . . . | 1 602 620# |
| Coal consumed November 1918 . . . . . . . . . . . . . . | 1 398 512# |
| Difference . . . . . . . . . . . . . . . . . . . . . . | 204 108# |
| | |
| Temperature November 1917 . . . . . . . . . . . . . | 37.5° |
| Temperature November 1918 . . . . . . . . . . . . . | 32.6° |
| Difference in temperature . . . . . . . . . . . . . | -4.9° |
| | |
| Correction for increased radiation (.07 x 1 602 620). | 112 183# |
| Correction for difference in temperature (4.9 x 14000) | 68 600# |
| Net saving (204 108 plus 112 183 plus 68600) . . . . . | 384 891# |

| | |
|---|---|
| Coal consumption for November 1917, corrected for temperature and radiation conditions of November 1918 (1 602 620 plus 112 183 plus 68 600) | 1 783 403# |
| Net saving in percent $\frac{384\ 891 \times 100}{1\ 783\ 403}$ . . . . . . . . . | 21.6% |
| Net saving in tons . . . . . . . . . . . . . . . . . . . | 192.45T. |
| Net saving in dollars at $7.50 per ton . . . . . . . . | $1 440.00 |

| | |
|---|---|
| Coal consumed December 1917 . . . . . . . . . . . . . . | 2 111 082# |
| Coal consumed December 1918 . . . . . . . . . . . . . . | 1 618 398# |
| Difference . . . . . . . . . . . . . . . . . . . . . . . | 492 684# |
| | |
| Temperature December 1917 . . . . . . . . . . . . . . . | 5.7° |
| Temperature December 1918 . . . . . . . . . . . . . . . | 23.2° |
| Difference in temperature . . . . . . . . . . . . . . . | 17.5° |
| | |
| Correction for increased radiation (.07 x 2 111 082). | 147 776# |
| Correction for difference in temperature (23.2 x 14000) | 245 000# |
| Net saving (2 111 082 plus 147 776 minus 245 000) . . . | 395 460# |
| | |
| Coal consumption for December 1917 corrected for temperature and radiationconditions of December 1918, (2 111 082 plus 147 776 minus 245 000) . . . | 2 013 858# |
| Net saving in percent $\frac{395\ 460 \times 100}{2\ 013\ 858}$ . . . . . . . . . | 19.7% |
| Net saving in tons . . . . . . . . . . . . . . . . . . . | 197.73T |
| Net saving in dollars at $7.50 per ton | $1 480.00 |

| | |
|---|---|
| Coal consumed January 1918 . . . . . . . . . . . . . . . | 2 271 559# |
| Coal consumed January 1919 . . . . . . . . . . . . . . . | 1 659 350# |
| Difference . . . . . . . . . . . . . . . . . . . . . . . | 612 209# |
| | |
| Temperature January 1918 . . . . . . . . . . . . . . . . | 2.9° |
| Temperature January 1919 . . . . . . . . . . . . . . . . | 18.1° |
| Difference in temperature . . . . . . . . . . . . . . . | 15.2° |
| | |
| Correction for increased radiation (.07 x 2 271 559). | 159 009# |
| Correction for difference in temperature (15.2 x 14000) | 212 800# |
| Net saving (612 209 plus 159 009 minus 212 800) . . . | 558 418# |
| | |
| Coal consumption for January 1918 corrected for temperature and radiation conditions of January 1919, (2 271 559 plus 159 009 minus 212 800) . . . . . . . . | 2 217 768# |
| Net saving in percent $\frac{558\ 418 \times 100}{2\ 217\ 768}$ . . . . . . . . . | 25.2% |
| Net saving in tons . . . . . . . . . . . . . . . . . . . | 279.21 |
| Net saving in dollars at $7.50 per ton . . . . . . . . | $2 095.00 |

The flue gas temperature, averaging 433 degrees is probably wrong, since for most of the month only one of the three return tubular boilers was in operation and air leakage thru the other

two would tend to lower the temperature of the gases passing the thermometer in its present location, although the temperatures also indicate that air leakage thru these boilers was less than ordinary. It would be well to place the flue thermometer in the breeching connecting to the large boiler when only one small boiler is being operated.

The needle valve for the gas collecting tank had become lost and a new one, while ordered, had not been received. Caustic potash had been ordered for flue gas analyses but not received. As a result, it was not possible to collect and analyze the flue gases.

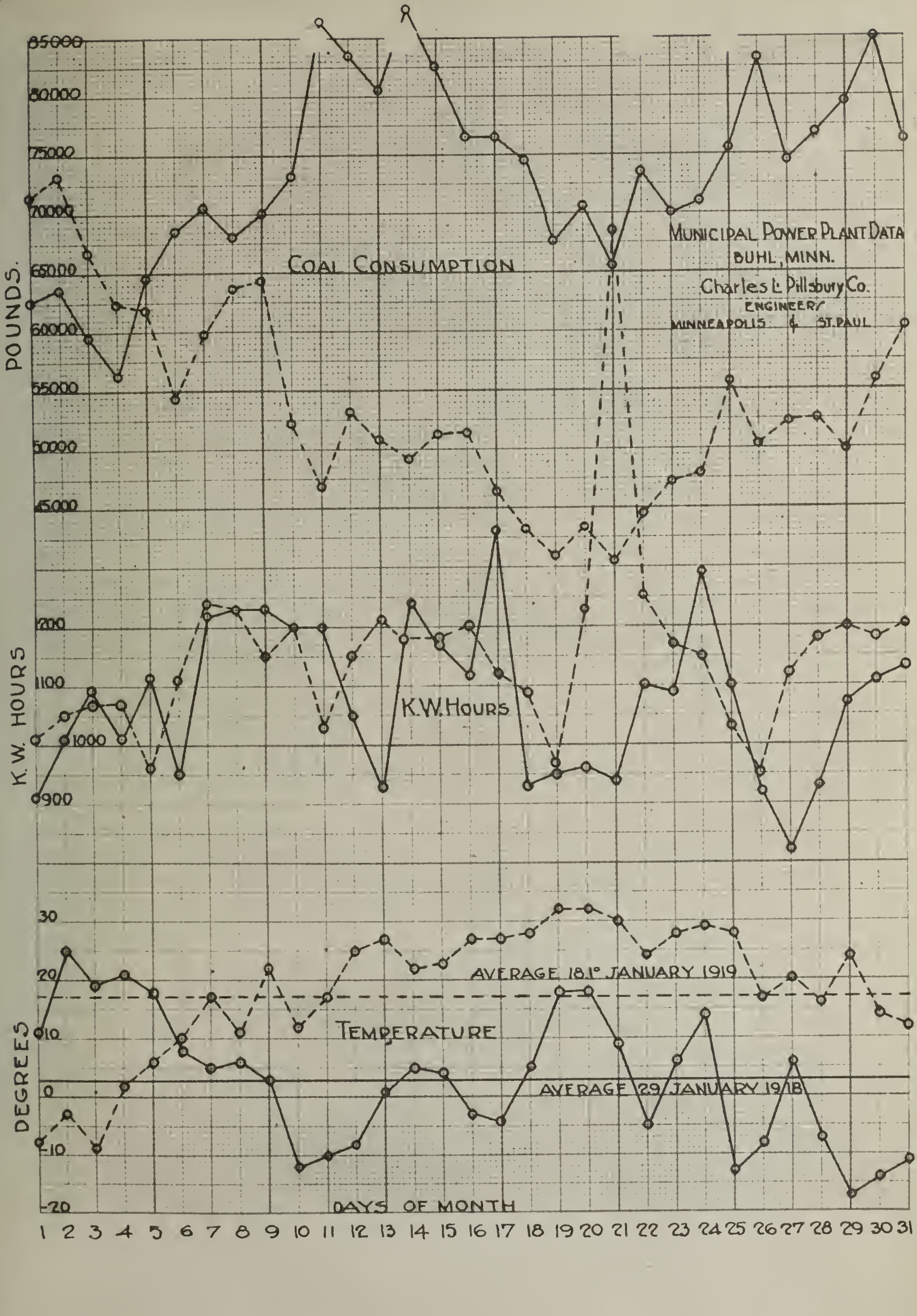
However, at the time of inspection, the furnace conditions appeared excellent and the carbon dioxide percentage would undoubtedly be high. The firemen were giving continuous and proper attention to the fires and apparently getting good results.

The $CO_2$ recorder which was found in the storeroom should be installed in connection with the gas collector and put into operation.

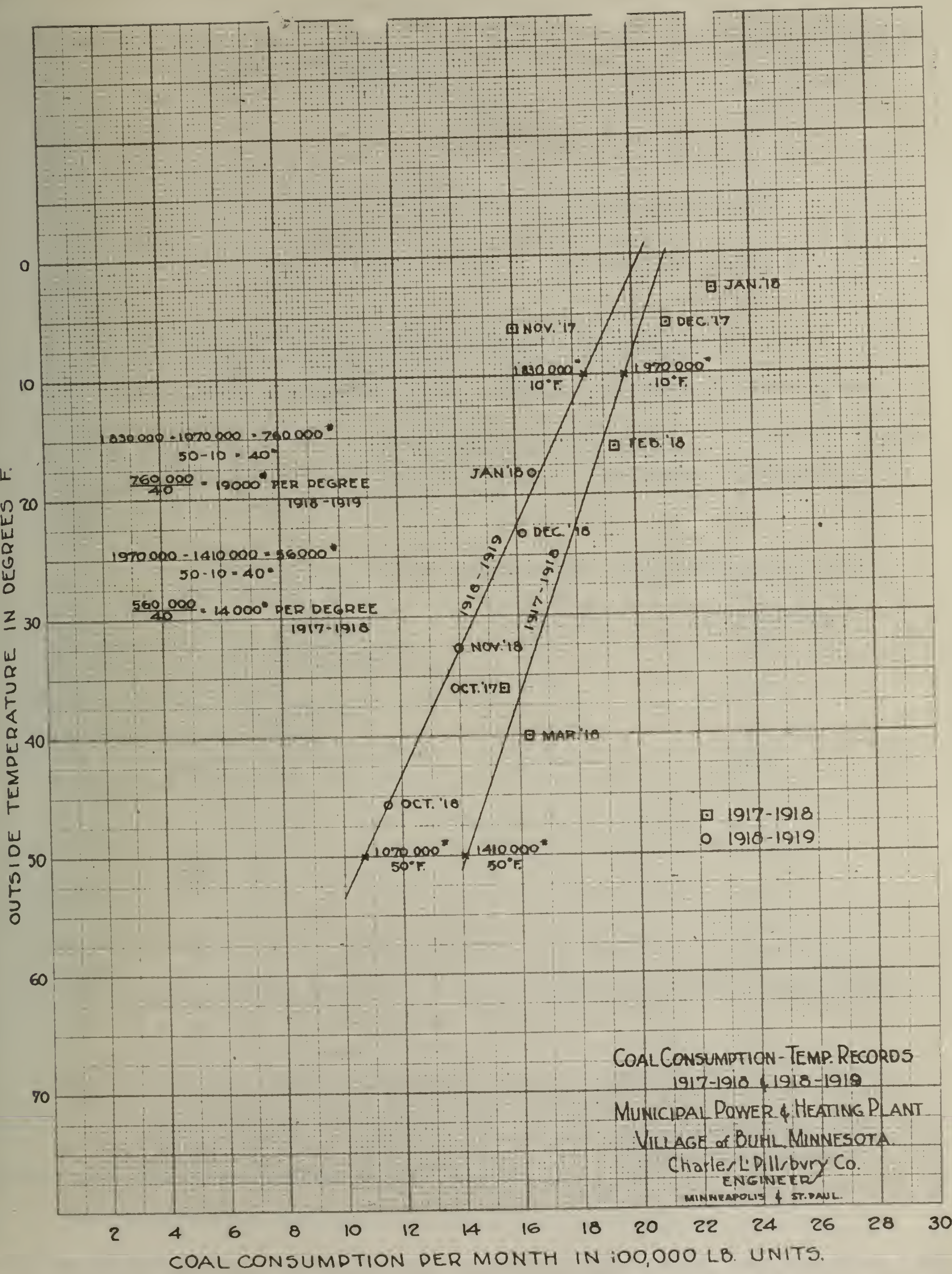
The front doors on the three small boilers were being fitted.

We have sent out specifications and requests for bids on a heater and meter, including one to Mr. Wm. Boyd, according to your instructions.

Yours very truly,
CHARLES L. PILLSBURY CO.
By O.C.


MUNICIPAL POWER PLANT DATA
BUHL, MINN.
Charles L. Pillsbury Co.
ENGINEERS
MINNEAPOLIS & ST. PAUL
COAL CONSUMPTION
POUNDS.
85000
80000
75000
70000
65000
60000
55000
50000
45000
K.W. HOURS
K.W. Hours
1200
1100
1000
900
TEMPERATURE
DEGREES
30
20
10
0
-10
-20
AVERAGE 18.1° JANUARY 1919
AVERAGE 2.9 JANUARY 1918
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

①


OUTSIDE TEMPERATURE IN DEGREES F.
0
10
20
30
40
50
60
70
COAL CONSUMPTION PER MONTH IN 100,000 LB. UNITS.
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
JAN. 18
DEC. 17
NOV. 17
1830 000#
10°F.
1970 000#
10°F.
FEB. 18
JAN. 19
DEC. 18
1918-1919
1917-1918
NOV. 18
OCT. 17
MAR. 18
OCT. 18
1070 000#
50°F.
1410 000#
50°F.
1830 000 - 1070 000 = 760 000#
50-10 = 40°
760 000 / 40 = 19000# PER DEGREE
1918-1919
1970 000 - 1410 000 = 56000#
50-10 = 40°
560 000 / 40 = 14 000# PER DEGREE
1917-1918
⊡ 1917-1918
○ 1918-1919
COAL CONSUMPTION - TEMP. RECORDS
1917-1918 & 1918-1919
MUNICIPAL POWER & HEATING PLANT
VILLAGE of BUHL MINNESOTA
Charles L. Pillsbury Co.
ENGINEERS
MINNEAPOLIS & ST. PAUL

Minneapolis
March 6
1919.

Village Water, Light, Heat, Power and Building Commission,

Buhl, Minnesota.

Gentlemen:-

In accordance with our contract, an inspection was made of your Municipal Plant, on March 4th, 1919. We have also received your power plant records for the month of February 1919, from which the following tabulation was made, together with the records for February 1918.

| | February 1918. | February 1919. |
|---|---|---|
| Total pounds of coal consumed | 1 935 251 | 1 585 221 |
| Outside temperature, degrees F. | 16 | 13 |
| Average horse power rating of boilers in operation | 757 | 568 |
| Pounds of coal per sq.ft. of grate surface per hour | 10.7 | 11.7 |
| Kilowatt hours per day - average | 1032 | 1185 |

The relative coal consumption, kilowatt hours, and outside temperatures for February 1918 and February 1919, are shown on accompanying curve sheet. The solid lines are for February 1918 and the dotted lines for February 1919. The data for compiling the accompanying tables and curves was taken from your power plant records.

The following tabulation shows the saving in fuel for February 1919 as compared with February 1918, and also summarizes the saving for the five months since October 1, 1918.

The saving for February is 273.8 tons, or 28.2% or $2050.00.

The saving for the five months is 1128.32 tons, or 23.8% or $8,450.00.

| | |
|---|---|
| Coal consumed February 1918 | 1 935 251# |
| Coal consumed February 1919 | 1 585 221# |
| Difference | 350 030# |

| | |
|---|---|
| Temperature January 1918 | 16° |
| Temperature January 1919 | 13° |
| Difference in temperatures | 3° |

| | |
|---|---|
| Correction for increased radiation (.07 x 1 935 251) | 155 668# |
| Correction for difference in temperature (3 x 14 000) | 42 000# |
| Net saving (350 030 plus 155 668 plus 42 000) | 547 698# |

| | |
|---|---|
| Coal consumption for February 1918 corrected for temperature and radiation conditions of February 1919, (1 935 251 plus 155 668 plus 42 000) | 2 132 919# |
| Net saving in percent $\frac{547\ 698 \times 100}{2\ 132\ 919}$ | 25.6% |
| Net saving in tons | 273.85T. |
| Net saving in dollars at $7.50 per ton | $2 050.00 |

The $CO_2$ recorder has been showing an average of about ten percent (10%). This is a fair average and far better than was being obtained last summer when the original investigation was made. However, the average should be fourteen percent (14%), and this figure should be strived for. The rate of combustion is low, only 11.7 pounds per square foot of grate surface, and with this rate it requires more watching of the fires to prevent holes forming and lowering the average $CO_2$. Effort should be made to keep down the number of boilers in operation as far as possible, in order to raise the combustion rate.

The question of substituting Mazda lamps for the present arc lights was taken up with our electrical engineer, and if you will send us the following information, we will advise you in the matter:

Total number of arc lamps in service.

Number of circuits served.

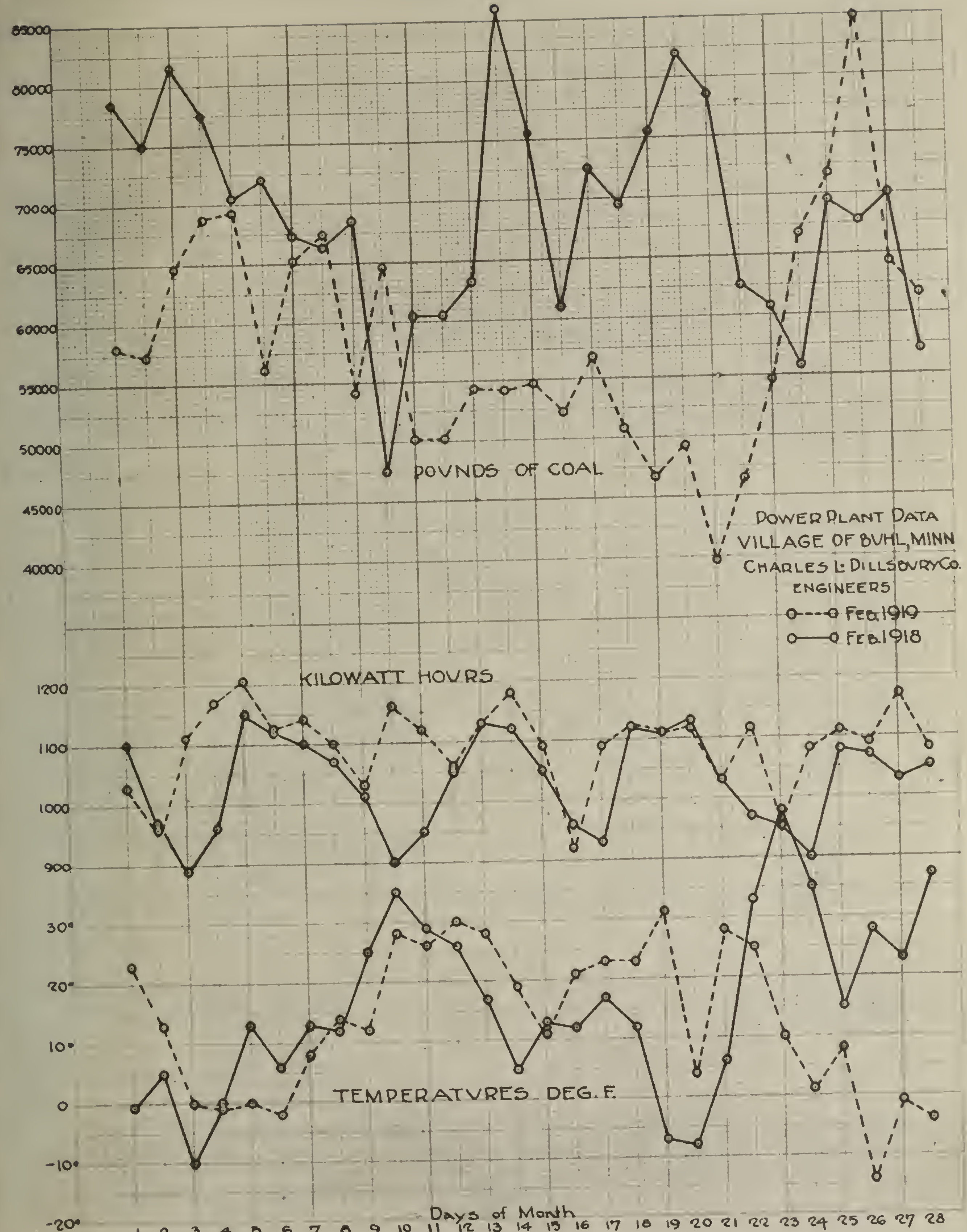
Number of arc lamps on each circuit.

Size of arcs.

Voltage.

All data on name plate on Constant Current Transformer.

Very truly yours,
CHARLES L. PILLSBURY CO.
By O.C.


85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
POVNDS OF COAL
POWER PLANT DATA
VILLAGE OF BVHL, MINN
CHARLES L. PILLSBVRY CO.
ENGINEERS
o---o Feb. 1919
o—o Feb. 1918
KILOWATT HOVRS
1200
1100
1000
900
30°
20°
10°
0
-10°
-20°
TEMPERATVRES DEG. F.
Days of Month
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

Minneapolis
April 12
1919.

Water, Light, Heat, Power and Building Commission,

Buhl, Minnesota.

Gentlemen:-

An inspection was made of your Municipal Heat, Light, and Water Plant, on April first, 1919. We have also received your plant records for the month of March 1919 and made an analysis of same.

The following tabulation compares the operation for March 1919, with March 1918 - the data for the tabulation being taken from your power plant records.

| | March 1918. | March 1919. |
|---|---|---|
| Total pounds of coal consumed | 1 633 443 | 1 647 363 |
| Outside temperature - degrees F. | 40 | 28.8 |
| Average horse power rating of boilers in operation | 590.4 | 500. |
| Pounds of coal per sq.ft. of grate surface per hour | 11.5 | 13.7 |
| Kilowatt hours per day - average | 924 | 1033 |

Correction in coal consumption and estimated saving in fuel is given as follows:

| | |
|---|---|
| Coal consumed March 1918 | 1 633 443# |
| Coal consumed March 1919 | 1 647 363# |
| Temperature - March 1918 | 40°F. |
| Temperature - March 1919 | 28.8°F. |
| Correction for increased radiation (.07 x 1 633 443) | 114 341# |
| Correction for difference in temperature (11.2x14000) | 156 800# |
| Net saving (1 633 433 plus 114 341 plus 156 800 minus 1 647 363) . . . . . . . . | 257 221# |
| Coal consumption for March 1918 corrected for temperature and radiation conditions of March 1919 (1 633 443 plus 114 341 plus 156 800) . . . . . . . | 1 904 584# |

| | | |
|---|---|---|
| Net saving in percent | $\frac{257\ 221 \times 100}{1\ 904\ 584}$ . . . . . . . . . . . | 13.5% |
| Net saving in tons | $\frac{257\ 221}{2000}$ . . . . . . . . . . . . . . | 128.61 |
| Net saving in dollars at \$7.50 per ton | . . . . . . . . . . | \$ 865.00 |

The fuel consumption compared with other months during the present heating season is high. There are two very definite reasons for this. The radial arches over the furnaces have developed serious leaks and admit an excessive amount of air. The openings in the arches can be detected by visual inspection, and the excess air is indicated by the charts from the $CO_2$ recorder. It is apparent that the fuel being used recently, or at least, at the time of inspection, was of a poorer grade than had been used in previous months. This coal seems to be higher in ash, and to have a lower fusing ash, causing trouble with clinkers. At the time of inspection it was noted that large clinkers formed on the grates and that clinkers adhered to and built up on the bridge walls. These conditions would also indicate that the coal was of a lower heat value. Clinker formation makes the care of fires more difficult, causes dead spots in the fires, and results in the passage of excess air, thus lowering the efficiency. It is also necessary to have the furnace doors open a greater portion of the time, causing a loss due to excess air.

More attention should be given to the fires to maintain them in efficient operating condition.

The furnace arches should be repaired as soon as possible. This is very important.

As to the fuel, we would advise the purchase of coal by analysis. The government regulation of coal has been removed and the sale of coal has become more competitive. It should now be

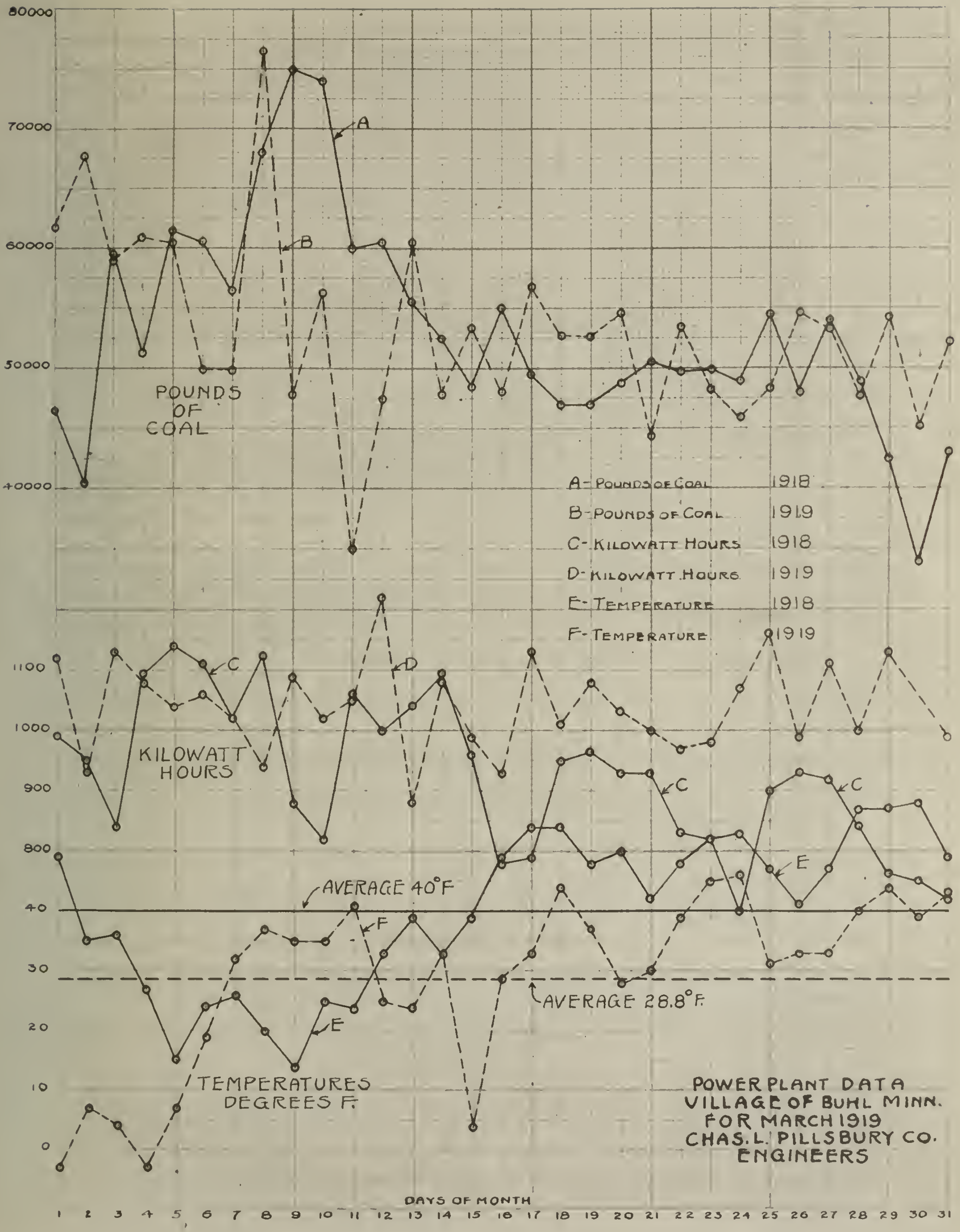
possible to purchase coal on the basis of quality as determined by analysis. It will be found that by buying coal by this method, a better grade can be obtained for a given price, a grade can be selected best adapted to your particular conditions, and in cases where the coal does not come up to grade, as shown by analysis, a rebate can be obtained under contract.

On the accompanying curve sheet is represented graphically, the variations of coal consumption, kilowatt hours, and outside temperatures for the months of March 1918 and March 1919. The curves show the coal consumption to be quite erratic during the month, particularly from the seventh to the thirteenth. The coal consumption curve, during the heating season should follow the temperature curve rather closely, where the temperature rises the coal consumption should decrease, and when the temperature falls, the coal consumption should increase and the increase or decrease in coal consumption should be proportional with the amount of fall or rise of temperature. Wherever these changes are out of proportion to each other, there is something wrong in operating condition.

We would suggest that, when your financial conditions permit, you consider the purchase and installation of new stokers for at least three small boilers. There are stokers now on the market which will effect such an increase in economy as to pay for themselves within three or four years. A large number of plants are now removing stokers which are of higher efficiency than those in your plant, and installing more modern types for the saving that can be effected. Three stokers of high efficiency could be purchased, with auxiliary equipment, and installed under the three small boilers for about $9,000.00, and the cost would be well

warranted in the saving of fuel effected.

Respectfully submitted,
CHARLES L. PILLSBURY CO.
By O.C.



POWER PLANT DATA
VILLAGE OF BUHL MINN.
FOR MARCH 1919
CHAS. L. PILLSBURY CO.
ENGINEERS

Minneapolis
May 9
1919.

Water, Light, Heat, Power and Building Commission,

Buhl, Minnesota.

Gentlemen:-

An inspection was made of your power plant May 6th 1919. We have also received your power plant reports for April 1919, from which, together with the records for April 1918, we have made the following tabulation of summaries for comparison:

| | April 1918. | April 1919. |
|---|---|---|
| Coal consumed during month | 1 199 897 | 1 244 960# |
| Outside temperature - degrees F. | 48. | 43.3 |
| Average horse power rating of boilers in operation | 485 | 435 |
| Pounds of coal per sq.ft. of grate surface per hour | 14.3 | 16.6 |
| Kilowatt hours per day - average | 788 | 989 |

The relative coal consumption, kilowatt hours, and outside temperatures for April 1918, and April 1919, are shown on accompanying curve sheet. The solid lines are for April 1918 and the dotted lines for April 1919. These curves were plotted from data taken from your power plant records.

The estimated saving of fuel in April 1919 as compared with April 1918, has been computed as follows:

| | |
|---|---|
| Coal Consumed - April 1918 | 1 199 897# |
| Coal Consumed - April 1919 | 1 244 960# |
| Temperature April 1918 | 48° |
| Temperature April 1919 | 43.3° |
| Correction for increased radiation (.07 x 1 199 897) | 83 693# |
| Correction for difference in temperature (4.7 x 14 000) | 65 800# |

| | |
|---|---|
| Net saving (1 199 897 plus 83 693 plus 65 800 minus 1 244 960) | 104 430# |
| Coal Consumption for April 1918 corrected for temperature and radiation conditions of April 1919 (1 199 897 plus 83 693 plus 65 800) | 1 349 390# |
| Net saving in percent $\frac{104\ 630 \times 100}{1\ 349\ 390}$ | 7.8% |
| Net saving in tons | 52.21T |
| Net saving in dollars at $7.50 per ton | $ 392.00 |

The percentage saving for April was the lowest of any month since October. This was due to the condition of the furnace arches and possibly to a considerable extent to the quality of coal. That the condition of the arches was to a large extent responsible, is evidenced by the $CO_2$ percentages obtained since putting the new boiler into service.

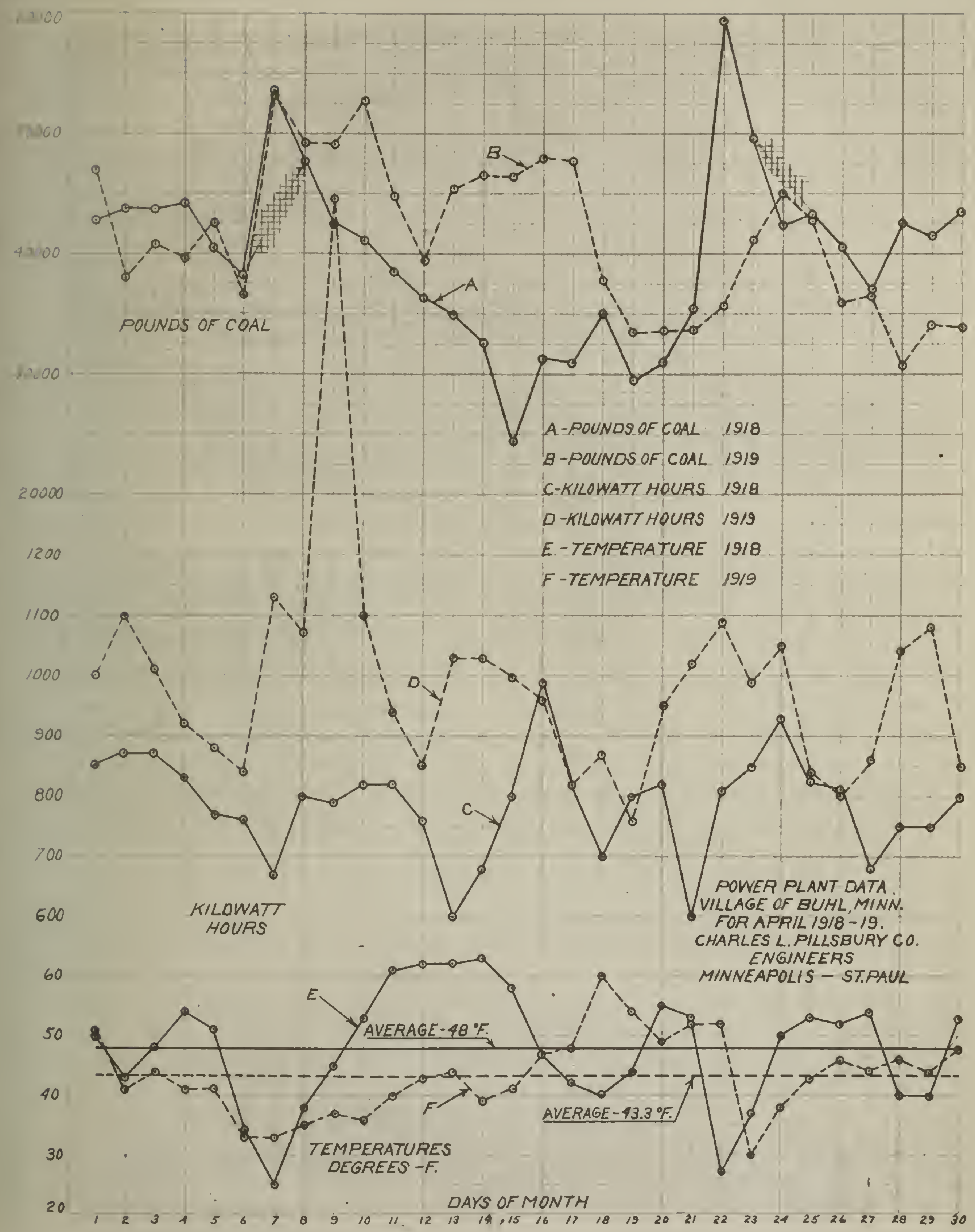
The new boiler is apparently operating satisfactory. The analyses of the flue gases from this boiler were averaging about 11. The new boiler appears to be very well installed with the exception of the breeching just outside the boiler room wall which is unwarrantably large.

In regard to the quality of coal, we would strongly recommend that before making a new contract for coal, the prospective contractors be required to submit proposals covering the quality of coal they propose to furnish, that is, the minimum heat content and maximum ash, sulphur and moisture, and that the coal be guaranteed to meet the specified quality on test. If a coal contract is made on this basis, a better quality of coal will be secured for the same price.

Respectfully submitted,

CHARLES L. PILLSBURY CO.

By O.C.


40000
30000
20000
1200
1100
1000
900
800
700
600
60
50
40
30
20
POUNDS OF COAL
B
A
A-POUNDS OF COAL 1918
B-POUNDS OF COAL 1919
C-KILOWATT HOURS 1918
D-KILOWATT HOURS 1919
E.-TEMPERATURE 1918
F-TEMPERATURE 1919
D
C
KILOWATT HOURS
POWER PLANT DATA.
VILLAGE OF BUHL, MINN.
FOR APRIL 1918-19.
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS - ST. PAUL
E
AVERAGE-48 °F.
F
AVERAGE-43.3 °F.
TEMPERATURES
DEGREES-F.
DAYS OF MONTH
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Minneapolis
June 16
1919.

Water, Light, Heat, Power and Building Commission,

Buhl, Minnesota.

Gentlemen:-

In accordance with our agreement, an inspection was made of your Municipal Plant, June 10 1919. We have also received your power plant records for the month of May 1919, from which the following tabulation was made, together with the records for May 1918.

| | May 1918. | May 1919. |
|---|---|---|
| Coal consumed during the month | 977 230 | 847 302 |
| Outside temperature - degrees F. | 59 | 59 |
| Average horse power rating of boilers in operation | 453 | 350 |
| Pounds of coal per sq.ft. of grate surface per hour | 12.1 | 13.55 |
| Kilowatt hours per day - average | 759 | 940 |
| Average carbon dioxide - percent | | 7.65 |

The relative coal consumption, kilowatt hours, and outside temperatures for May 1918 and May 1919 are shown on the accompanying curve sheet. The solid lines are for May 1918 and the dotted lines for May 1919. The data for plotting the curves was taken from your power plant records.

The net saving in operation in May 1919, as compared with May 1918, corrected for difference in average temperature and amount of radiation served, is determined by the following:

| | |
|---|---|
| Coal Consumed - May 1918 | 977 230# |
| Coal Consumed - May 1919 | 847 302# |
| Difference | 129 928# |
| | |
| Temperature - May 1918 | 59° |
| Temperature - May 1919 | 59° |
| Difference | 0° |

| | |
|---|---|
| Correction for increased radiation (.07 x 977 230) | 68 406# |
| Correction for difference in temperature (0 x 14 000) | 0 |
| Net saving (129 928 plus 68 406) | 198 334 |
| Coal consumption for May 1918 corrected for temperature and radiation conditions of May 1919 (977 230 plus 68 406) | 1 045 636 |
| Net saving in percent $\frac{198\ 334 \times 100}{1\ 045\ 636}$ | 19.0% |
| Net saving in tons | 99.17 |
| Net saving in dollars at $7.50 per ton | $744.00 |

The saving in coal, shown is not what it should be - particularly with the new boiler in operation during the greater part of the month. At the time of inspection, boiler No. 5 was down and boilers Nos. 2 and 3 in operation. While there has been a decided improvement in the way the firemen are handling their fires, they could still improve materially by taking care to keep the grates well covered with a good bed of fuel and to keep the dampers throttled as much as possible as to still permit carrying the loads. They should also be instructed to watch the $CO_2$ recorder, and to make an effort to keep the $CO_2$ as near to 15% as possible.

Doubtless the coal consumption was greater during May due to the feed water heater being out of service part time, but at that, the low $CO_2$ would also account for greater consumption, the average $CO_2$ on the record sheets being 7.65%, and at the time of inspection, the recorder was showing 8% and 9%.

It appears that the air compressor is still operated evenings during the period of peak electrical load. The average time of operation of the compressor during May was about ten hours per day, and it would seem that with the compressor only operating on an average of ten hours out of twenty-four hours, it would be possible to

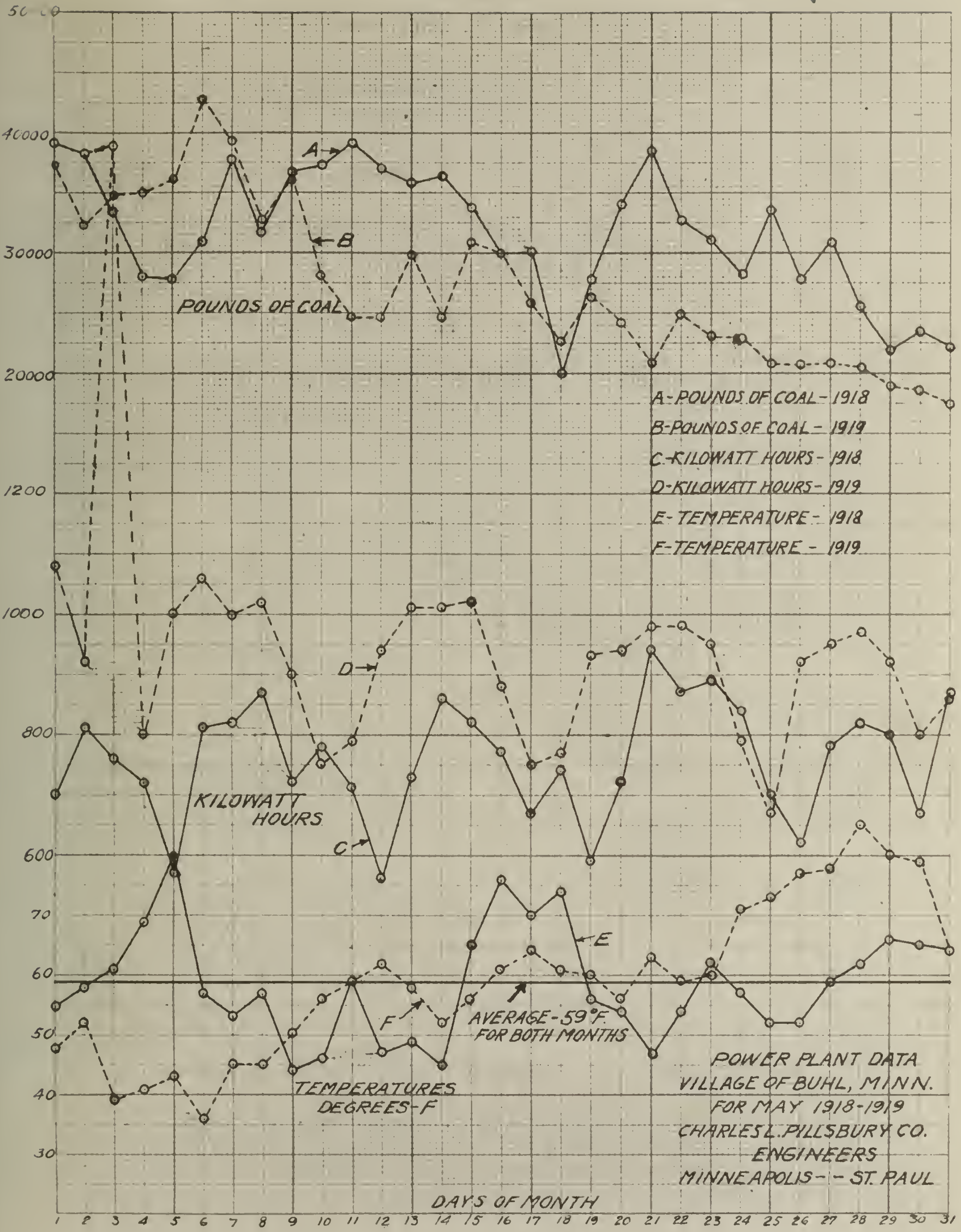
avoid operating it during the short time the peak loads occur.

We feel that with the new feed water heater in, and proper furnace operation, the coal saving during the summer months should average twenty-five percent (25%).

There seems to be some discrepancy in the electrical meter readings. For example, on May 3d and 4th, the totaling watt meter showed 1780 kilowatt while the calculated wattage from the volts, amperes and power factor of machines in operation was 890 kilowatt.

Liptak's crew seems to be doing very good work in laying the arches.

Respectfully submitted,
CHARLES L. PILLSBURY CO.
By O.C.


50000
40000
30000
20000
1200
1000
800
600
70
60
50
40
30
A
B
POUNDS OF COAL
KILOWATT HOURS
D
C
E
F
AVERAGE - 59°F. FOR BOTH MONTHS
TEMPERATURES DEGREES - F
A - POUNDS OF COAL - 1918
B - POUNDS OF COAL - 1919
C - KILOWATT HOURS - 1918
D - KILOWATT HOURS - 1919
E - TEMPERATURE - 1918
F - TEMPERATURE - 1919
POWER PLANT DATA
VILLAGE OF BUHL, MINN.
FOR MAY 1918-1919
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS - - ST. PAUL
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Minneapolis
July 12
1919.

Water, Light, Power and Building Commission,
Buhl, Minnesota.

Gentlemen:-

An inspection was made of your power plant July 4th, in accordance with our agreement. Your records for June 1919 have been received and the tabulation below, summarizes the data. The data for June 1917 is tabulated in comparison as our files do not contain any records of your plant for June 1918, but only from June 1917 to May 1918 inclusive, and we can only compare present operation with the corresponding period in that year.

| | June 1917 | June 1919 |
|---|---|---|
| Total coal consumed - pounds | 702 765 | 641 244 |
| Average kilowatt hours per day | 667 | 776 |
| Horse power rating of boilers in service - average | 301.5 | 287 |
| Pounds of coal per sq.ft. of grate surface - average | 13.5 | 13 |
| Outside temperature - degrees F. | 67 | 72 |
| Gallons of water pumped per day - average | | 209 066 |
| Temperature of flue gases Average - Degrees F. | | 435 |
| Temperature of boiler feed water Average - Degrees F. | | 204.6<br>(10 days average) |
| Carbon dioxide - percent - average | | 10.5<br>(15 days average) |

The accompanying blue print shows graphically, the variation of coal consumption, kilowatt hours generated, carbon dioxide in the flue gases, and the outside temperatures, by days, for the month of June 1917 and June 1919. The solid line curves are for June 1917, and the dotted line curves for June 1919.

The average temperature for each of the months is above that requiring the plant to furnish steam for heat. The curves would indicate that in each month there were short periods during which some steam heat was possibly required, but this was about the same in each case, and the temperatures at such times were such as to require little if any, live steam.

Comparison of the output of the plant would then be on the basis of kilowatt hours at the switchboard and gallons of water pumped. We have no record of the water pumped in June 1917, but this is likely to be less rather than more than pumped in June 1919. In making the following comparison then, we are assuming the plant output to be increased in June 1919 over June 1917 by the increase in electrical output.

| | |
|---|---|
| Coal consumed - June 1917 | 702 765# |
| Coal consumed - June 1919 | 641 244# |
| Difference | 61 521# |
| Kilowatt hours output - June 1917 (ave. per day) | 667 |
| Kilowatt hours output - June 1919 (ave. per day) | 776 |
| Difference | 109 |
| Percent increase in electrical output $\frac{109 \times 100}{667}$ | 16.3 |
| Equivalent coal for increased electrical output (702 765 x 0.163) | 114 500# |
| Coal consumption for June 1917 corrected for load conditions of June 1919 (702 765 plus 114 500) | 817 265# |
| Net saving in coal (61 521 plus 114 500) | 176 021# |
| Tons saving | 88.01 |
| Percent saving $\frac{176\ 021 \times 100}{817\ 265}$ | 21.6 |
| Saving in dollars (88 x $7.43 per ton) | $ 654.00 |

At present one small boiler is being operated to carry the load while during past summer seasons, two boilers have always

been in operation, and the present load on the plant is greater, at least during the periods indicated above.

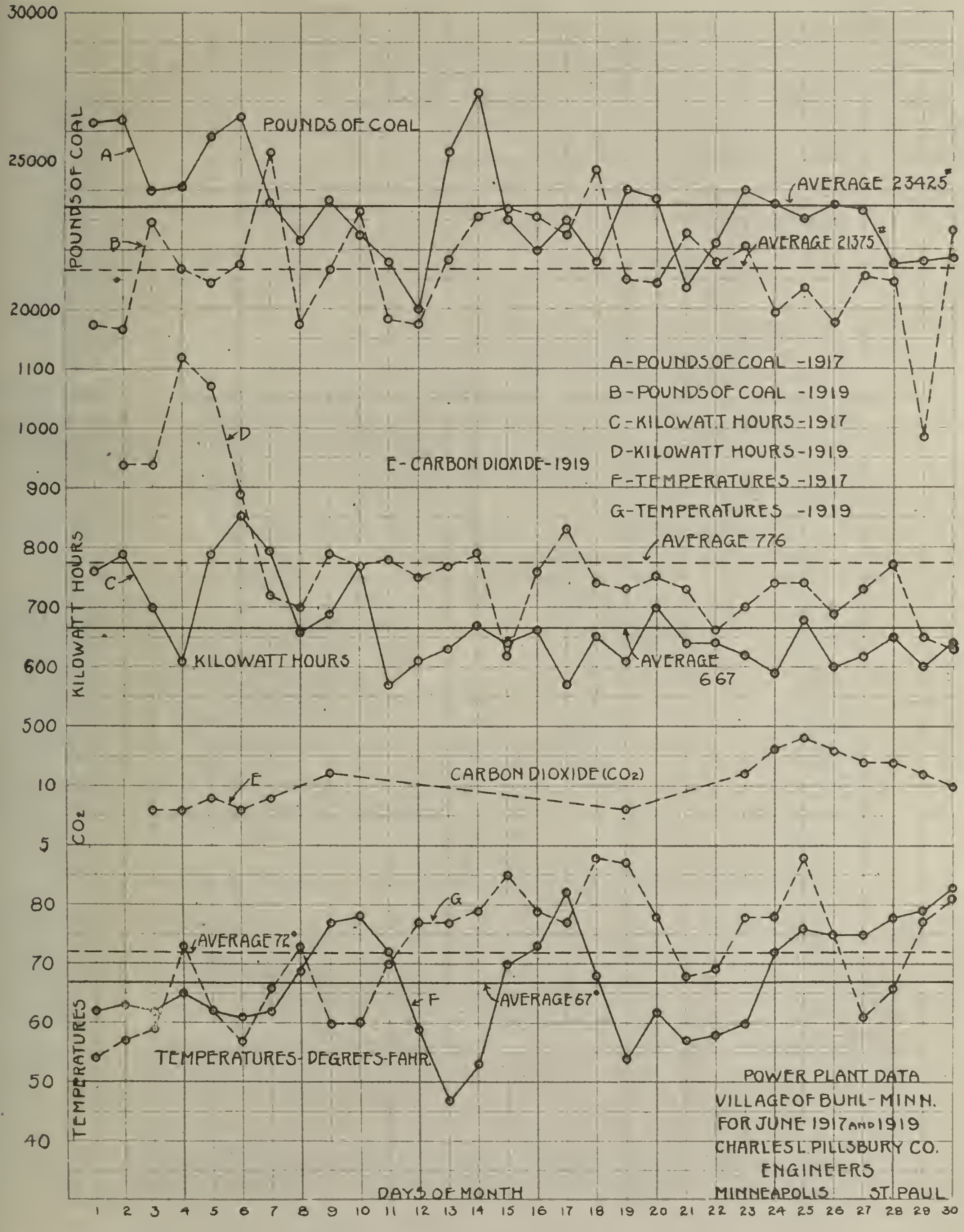
The furnace arches, have been repaired and this makes the boiler operation easier, and makes the carrying of the load on one boiler easier.

At the time of inspection the $CO_2$ recorder was showing analysis from 14% to 16% - an excellent average. The fire carried in the boiler at that time was in excellent condition.

The feed water heater is operating satisfactorily -- the temperature at the time of inspection being almost constantly 212 degrees. The temperature sometimes rises above this, creating a back pressure on the return tank, from which the water is fed to the heater. It would be well to have a pipe connecting from the heater to the top of this tank to balance the pressure.

We assume that the measuring and recording device will soon be installed on the meter and we feel confident that the readings will show a high rate of evaporation per pound of coal.

Very truly yours,
CHARLES L. PILLSBURY CO.
By O.C.


POUNDS OF COAL
A
B
AVERAGE 23425
AVERAGE 21375
A - POUNDS OF COAL - 1917
B - POUNDS OF COAL - 1919
C - KILOWATT HOURS - 1917
D - KILOWATT HOURS - 1919
E - CARBON DIOXIDE - 1919
F - TEMPERATURES - 1917
G - TEMPERATURES - 1919
D
C
AVERAGE 776
KILOWATT HOURS
AVERAGE 667
CARBON DIOXIDE (CO₂)
E
G
AVERAGE 72°
F
AVERAGE 67°
TEMPERATURES - DEGREES - FAHR.
POWER PLANT DATA
VILLAGE OF BUHL - MINN.
FOR JUNE 1917 AND 1919
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS ST. PAUL
DAYS OF MONTH
KILOWATT HOURS
CO₂
TEMPERATURES
30000
25000
20000
1100
1000
900
800
700
600
500
10
5
80
70
60
50
40
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Minneapolis
August 26
1919.

Water and Light Board,

Buhl, Minnesota.

Gentlemen:-

An inspection was made of your power plant, Tuesday, August 19, 1919. Your power plant records for July 1919 have been received and the following tabulation summarizes the operation for July 1917 for the purpose of comparison. As stated in our last report, we do not have in our files records of your plant operation for 1918.

| | July 1917. | July 1919. |
|---|---|---|
| Total pounds of coal consumed | 688 779 | 588 137 |
| Average horse power rating of boilers in operation | 299.6 | 150. |
| Pounds of coal per sq.ft. of grate surface per hour - average | 9.6 | 22. |
| Kilowatt hours generated - Ave per day | 660. | 775.5 |
| Outside temperature | 79. | 77.5 |
| Carbon Dioxide - percent - average | | 11.9 |
| Feed water temperature - average | | 203° F. |
| Flue gas temperatures - average | | 384° F. |

The actual pounds of coal used in July 1919 was less than in July 1917, altho the load on the plant was greater. The estimated saving on the basis that the increase in load on the plant was represented by the difference in electrical load is determined below:

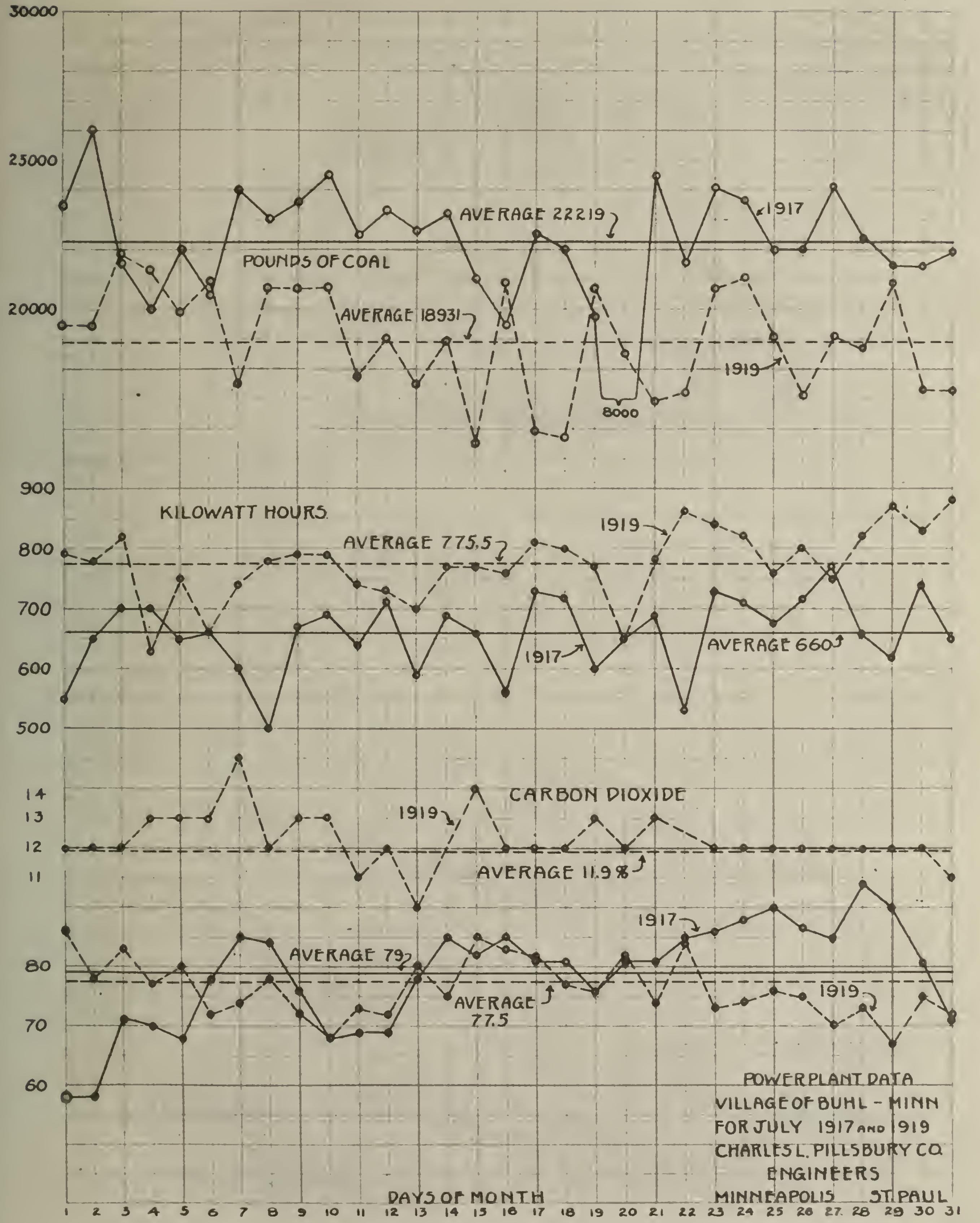
| | |
|---|---|
| Coal consumed July 1917 | 688 779# |
| Coal consumed July 1919 | 588 137# |
| Difference | 100 642# |
| | |
| Kilowatt hours delivered, Ave. per day, July 1917 | 660. |
| Kilowatt hours delivered, Ave. per day, July 1919 | 775.5 |
| Increase | 115.5 |
| Percent increase $\frac{115.5 \times 100}{660}$ | 17.5% |
| Correction in coal consumption for increased load (.175 x 688 779) | 121 000# |
| Net saving (100 641 plus 121 000) | 221 642# |

| | |
|---|---|
| Net saving in tons | 110.82 Tons |
| Net saving in percent $\frac{221\ 641 \times 100}{688\ 779 \text{ plus } 121\ 000}$ | 27.4% |
| Net saving in Dollars (110.8 x 7.43) | $825.00 |

The month of July 1919 has been the most satisfactory, from the standpoint of economy in operation, of any month during the past year. The percentage of fuel saving was exceptionally high, the average percentage of carbon dioxide in the flue gases was excellent, and the feed water temperature is near the maximum possible since installing the new heater. The flue temperatures as recorded are probably lower than actual since only one boiler was in operation and the gases from this boiler were probably diluted with air in the breeching by air infiltration past the dampers in the other boilers.

The new feed water heater is operating quite satisfactorily and heating the feed water so much higher than the old heater that it will soon pay for itself. The mèter however, is not operating satisfactorily as there is an extreme fluctuation in the flow of water from the return tank. This tank has become too small for the service imposed on it and its elevation is too low. We would recommend that a hot water float control be put in the heater and that a new tank of about 1200 gallons capacity be placed above the boiler room roof, supported by the boiler room walls, the tank either being housed or insulated with about three inches of asbestos and lagged with wood for protection against the weather.

Respectfully submitted,
CHARLES L. PILLSBURY CO.
By O.C.



POWER PLANT DATA
VILLAGE OF BUHL - MINN
FOR JULY 1917 AND 1919
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS ST. PAUL

Minneapolis
September 12
1919.

Water and Light Board,

Buhl, Minnesota.

Gentlemen:-

An inspection was made of your power plant, Monday, September 8, 1919. Your records for the month of August have been received and the following tabulation compares the operation of that month with the month of August 1917.

| | August 1917. | August 1918. |
|---|---|---|
| Total pounds of coal consumed | 723 223 | 547 024 |
| Total kilowatt hours output | 22 690 | 26 170 |
| Horse power rating of boilers in operation - average | 301.4 | 150 |
| Pounds of coal per sq.ft. of grate surface per hour | 13.5 | 20.4 |
| Outside temperature - average | 64.2 | 68.5 |
| Carbon dioxide percent - average | | 11.3 |
| Feed water temperature - Degrees F. Ave. | | 206. |
| Temperature of flue gases - Degrees F. Ave. | | 363. |

Since the temperature during the month was above that requiring live steam for heating purposes, an estimate of fuel saving should be based on comparative power output, which basis is used in the following calculations:

| | |
|---|---|
| Coal Consumed - August 1917 | 723 223 |
| Coal Consumed - August 1919 | 547 024 |
| Difference | 176 199 |
| | |
| Kilowatt hours output - August 1917 | 22 690 |
| Kilowatt hours output - August 1919 | 26 170 |
| Increase | 3 480 |
| Percent increase $\frac{3480 \times 100}{22\ 690}$ | 15% |
| Correction in coal consumption for increased load (0.15 x 723,223) | 108 483 |
| Net saving (176 199 plus 108 483) | 284 682 |

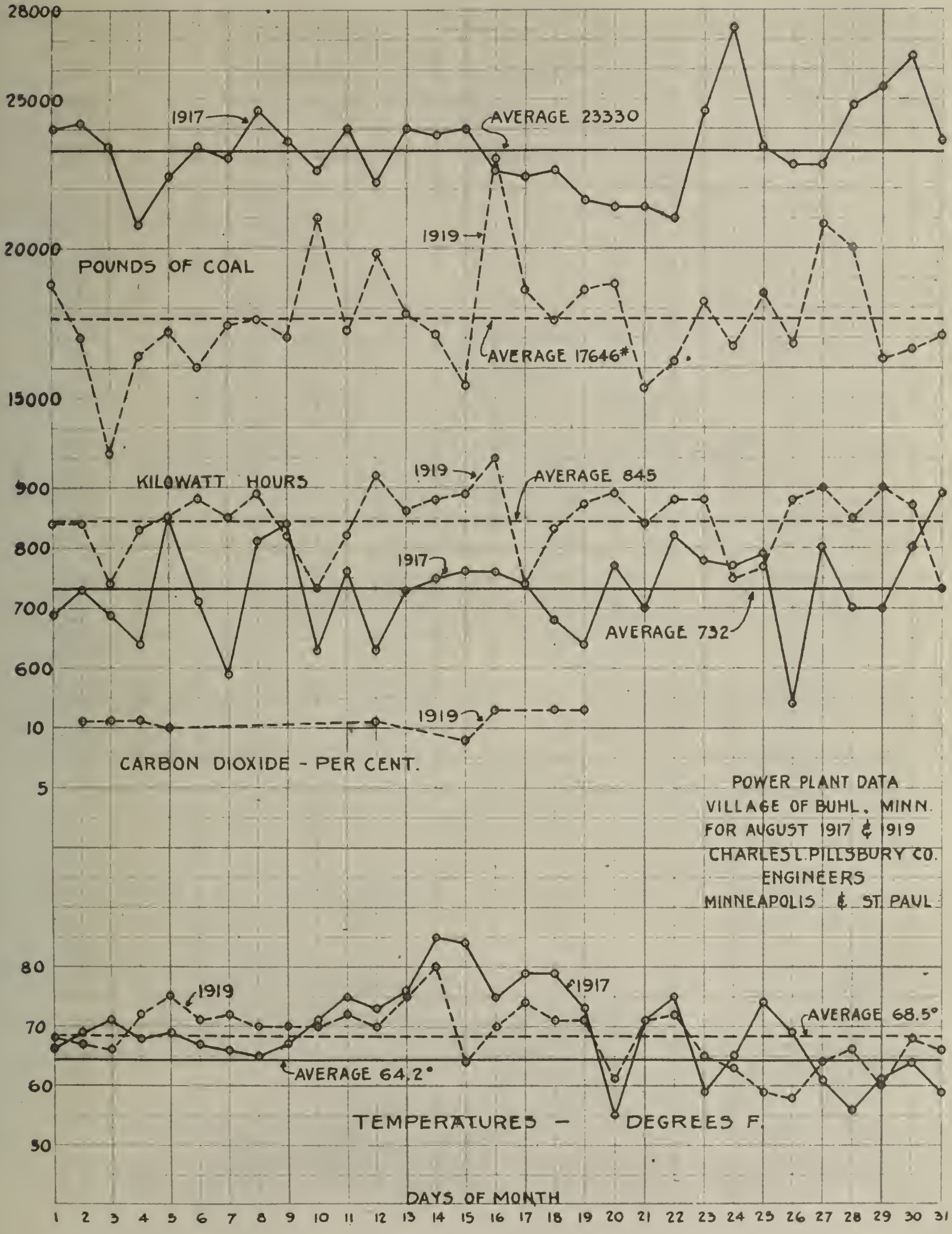
| | |
|---|---|
| Net saving in tons | 142.34 T. |
| Net saving in dollars (73% at $7.43 and<br>27% at $6.74) | $1 030.00 |
| Net saving in percent $\frac{284\ 682 \times 100}{723\ 223 \text{ plus } 108\ 223}$ | 34.2 % |

The month of August was on par with the month of July as regards economy and efficiency of operation. However, the writer noted that load conditions had become such that it was necessary to operate the large engine the most of the time in order to meet unexpected peaks. This is making the operation of one boiler difficult particularly with the grade of coal that was on hand. Every effort however, should be made to carry the load with the one boiler as long as possible, and when it does become necessary to operate two boilers, more than ordinary attention should be given the fires, as it will be more difficult to keep them in proper condition with lighter load on each boiler.

Very truly yours,

CHARLES L. PILLSBURY CO.

By O.C.


28000
25000
20000
15000
900
800
700
600
10
5
80
70
60
50
1917
AVERAGE 23330
1919
POUNDS OF COAL
AVERAGE 17646*
KILOWATT HOURS
1919
AVERAGE 845
1917
AVERAGE 732
1919
CARBON DIOXIDE - PER CENT.
POWER PLANT DATA
VILLAGE OF BUHL, MINN.
FOR AUGUST 1917 & 1919
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS & ST. PAUL
1919
1917
AVERAGE 68.5°
AVERAGE 64.2°
TEMPERATURES — DEGREES F.
DAYS OF MONTH
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Minneapolis
January 7
1920.

Water and Light Board,

Buhl, Minnesota.

Gentlemen:-

In accordance with our contract, an inspection was made of your power plant, on October 16, 1919. Your power plant records for September 1919, have been received, and an analysis of operation in comparison with that of September 1917, follows:-

| | Sept. 1917. | Sept. 1919. |
|---|---|---|
| Total Pounds of Coal | 805 984 | 729 004 |
| Total Kilowatt hours generated | 26 940 | 31 650 |
| Pounds of coal per sq.ft. of grate surface per hour | 15.5 | 15.1 |
| Outside temperature - Average | 63.5 | 59.9 |
| Carbon Dioxide Percent - Average | | 10.4 |
| Feed Water Temperature - Average | | 196° |
| Flue Gas Temperature - Average | | 407° |

Correction in coal consumption and estimated saving in fuel follows:-

| | |
|---|---|
| Coal Consumed - September 1917 | 805 984 |
| Coal Consumed - September 1919 | 729 004 |
| Temperature - September 1917 | 63.5 |
| Temperature - September 1919 | 59.9 |
| Correction for increased radiation (.08 x 729 000) | 58 320# |
| Correction for difference in temperature (14 000 x 3.6) | 50 400# |
| Net Saving (76 980 plus 58 320 plus 50 400) | 185 700# |
| Net Saving in percent $\frac{185\ 704 \times 100}{914\ 704}$ | 20.3% |
| Net Saving in tons | 92.85 |
| Net Saving in Dollars ($6.74 per Ton) | $625.81 |

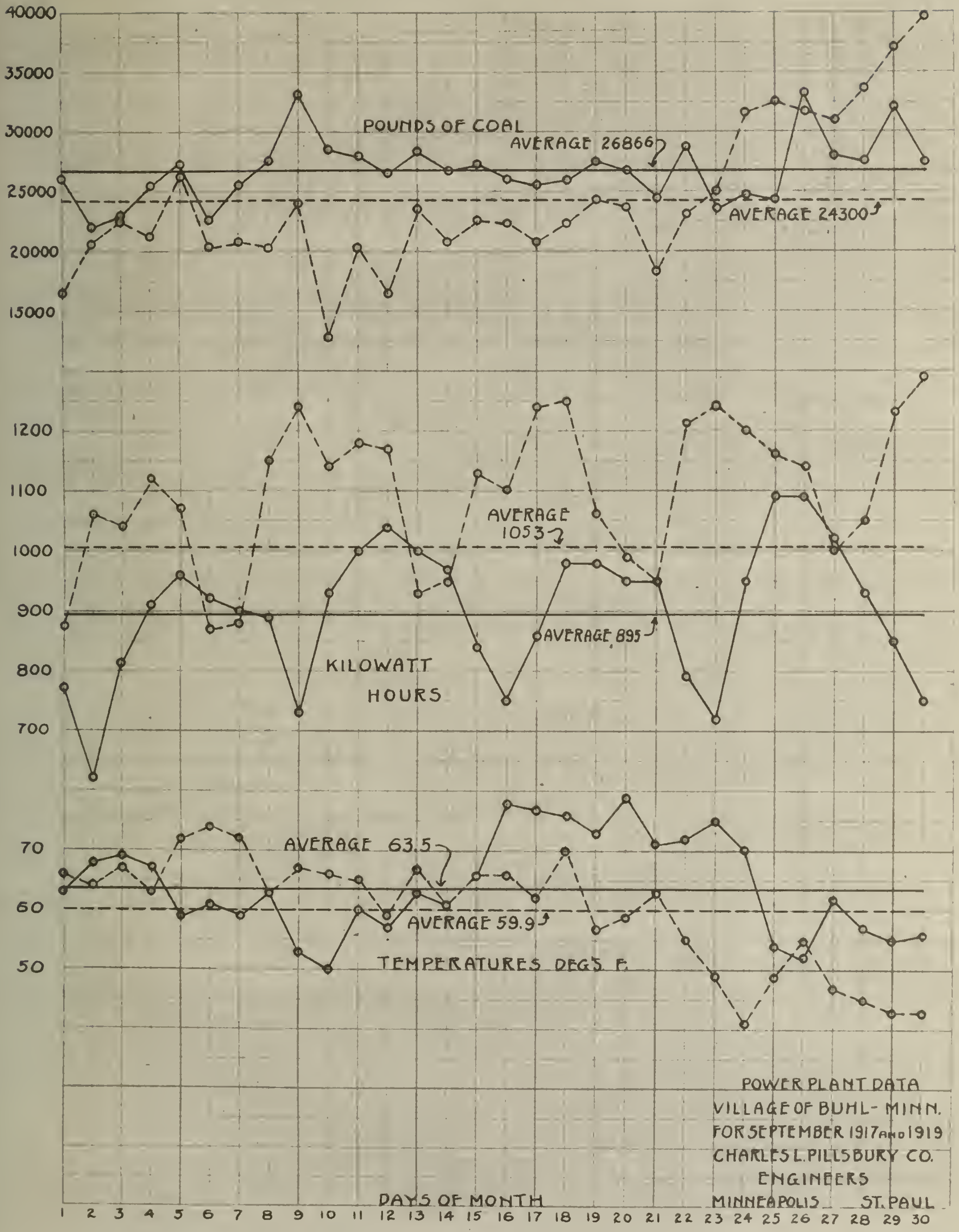
Altho your electrical generated output for September 1919, was 17½% greater than in September 1917, we have not corrected the coal consumption accordingly. We believe however, that the saving noted above of 20.3% would be increased by several percent were we able to determine this factor.

In general, it may be said that the September operation was efficient in comparison to other months.

We have made a correction in the total amount of coal as noted on your summary sheet, due to the fact that on the 9th, you show a consumption of 204 648 pounds, which should have been 24 054 pounds, as noted on your daily log sheet.

We are enclosing herewith, a chart, showing a comparison of daily plant operation for September 1917 and 1919.

Very truly yours,
CHARLES L. PILLSBURY CO.
By O.C.



POWER PLANT DATA
VILLAGE OF BUHL - MINN.
FOR SEPTEMBER 1917 AND 1919
CHARLES L. PILLSBURY CO.
ENGINEERS
MINNEAPOLIS ST. PAUL

## SUMMARY

The diagrams on pages 109 and 110 show operating conditions for the two years, 1917-1918 and 1918-1919, summarized.

On page 109 curve (A) shows the average horse power rating of boilers in operation during each month 1917-1918, and curve (B) shows the horse power rating of boilers in operation during each month 1918-1919. Curve (C) is the difference and indicates the amount by which the boilers in service was reduced. This reduction in amount of boilers in service is equivalent to practically one of the 150 H.P. boilers and is attributable to two things; less actual coal burned andmore production from coal burned.

In the diagrams in connection with the first report, pages 32 to 56 are a series of plottings between evaporation and percent rating on boilers. These diagrams show that in general, increasing the load carried by the boilers, increases the evaporation or efficiency. This was true in this particular case because the loads were so light compared with the ratings of the boilers in operation. There is of course, a point of loading for maximum efficiency and this point varies with the boiler, setting, furnace, stoker and coal. However, it is probable that the maximum is near 130% rating for these boilers, and it was for this reason that continual stress was put on the point of loading. The reduction in rated boiler horse power in operation was partly due to this cause.

Boiler loading is important. The writer has in quite a number of cases, improved the efficiency of boiler room operation, simply by reducing the number of boilers operated.

On page 110 curve (A) shows the actual coal consumption each

month 1918-1919, curve (B) shows the actual coal consumption each month 1917-1918, curve (C) shows the coal consumption each month 1917-1918 corrected for temperature and load conditions of 1918-1919, and curve (D) shows the percent difference between (A) and (C), or the net saving of coal in percent by months. On this same diagram are shown the electrical loads in terms of average kilowatt hours per day for each month for each of the two years, and the average monthly outside temperatures for each of the two years.

The actual coal consumption for the year 1918-1919 was 13 656 063 pounds; for the year 1917-1918, the actual coal consumption was 16 197 354 pounds, and the coal consumption for 1917-1918 corrected for load and temperature differences was 17 340 319 pounds.

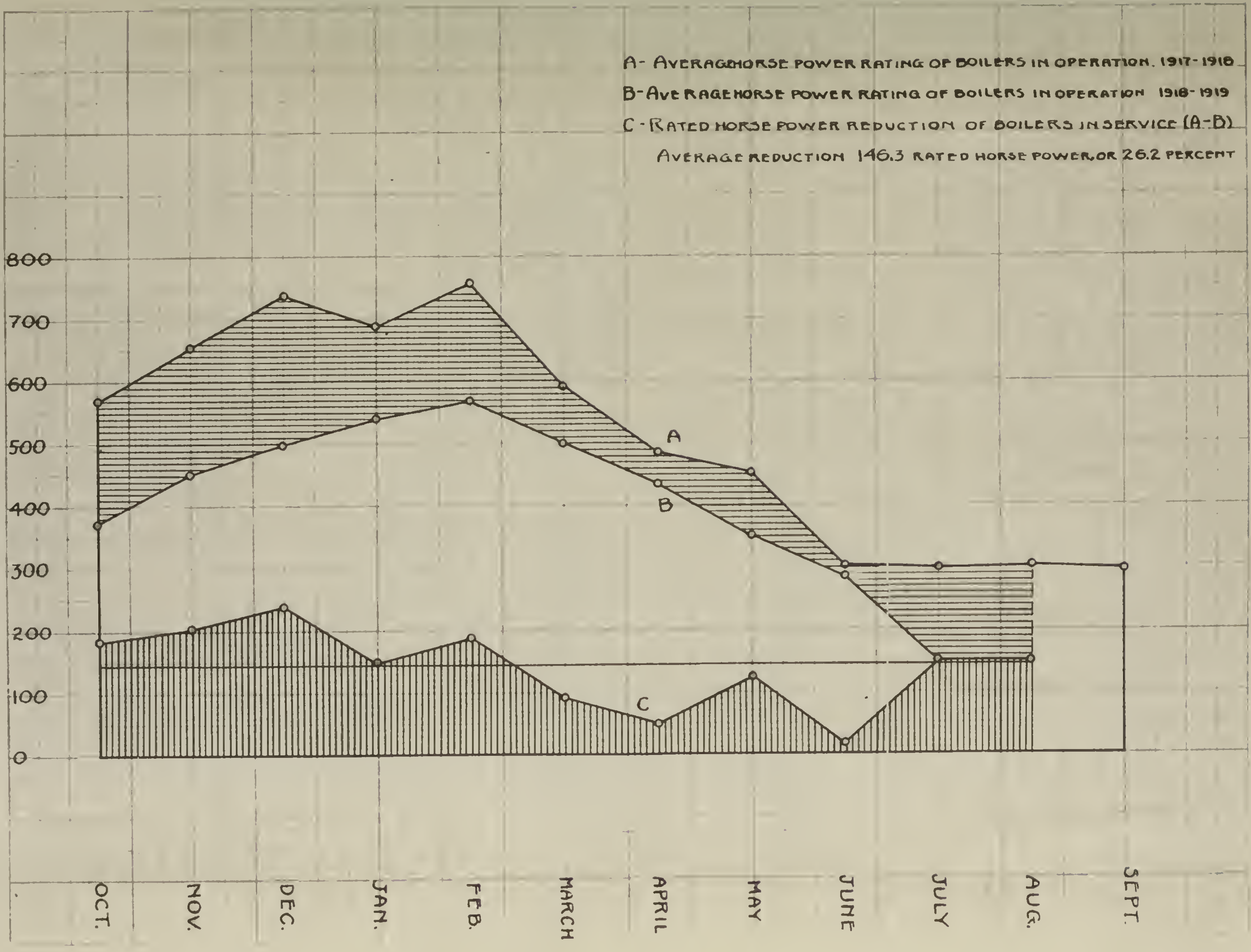
The actual difference in coal consumption between the two years was 2 541 291 pounds and the corrected difference was 3 684 256 pounds. There was an actual reduction of 15.7% in the amount used, and the corrected difference was 21.2% of the corrected consumption, which figure represents the net saving in percent. The difference in the two percentages represents the difference in load and temperatures.

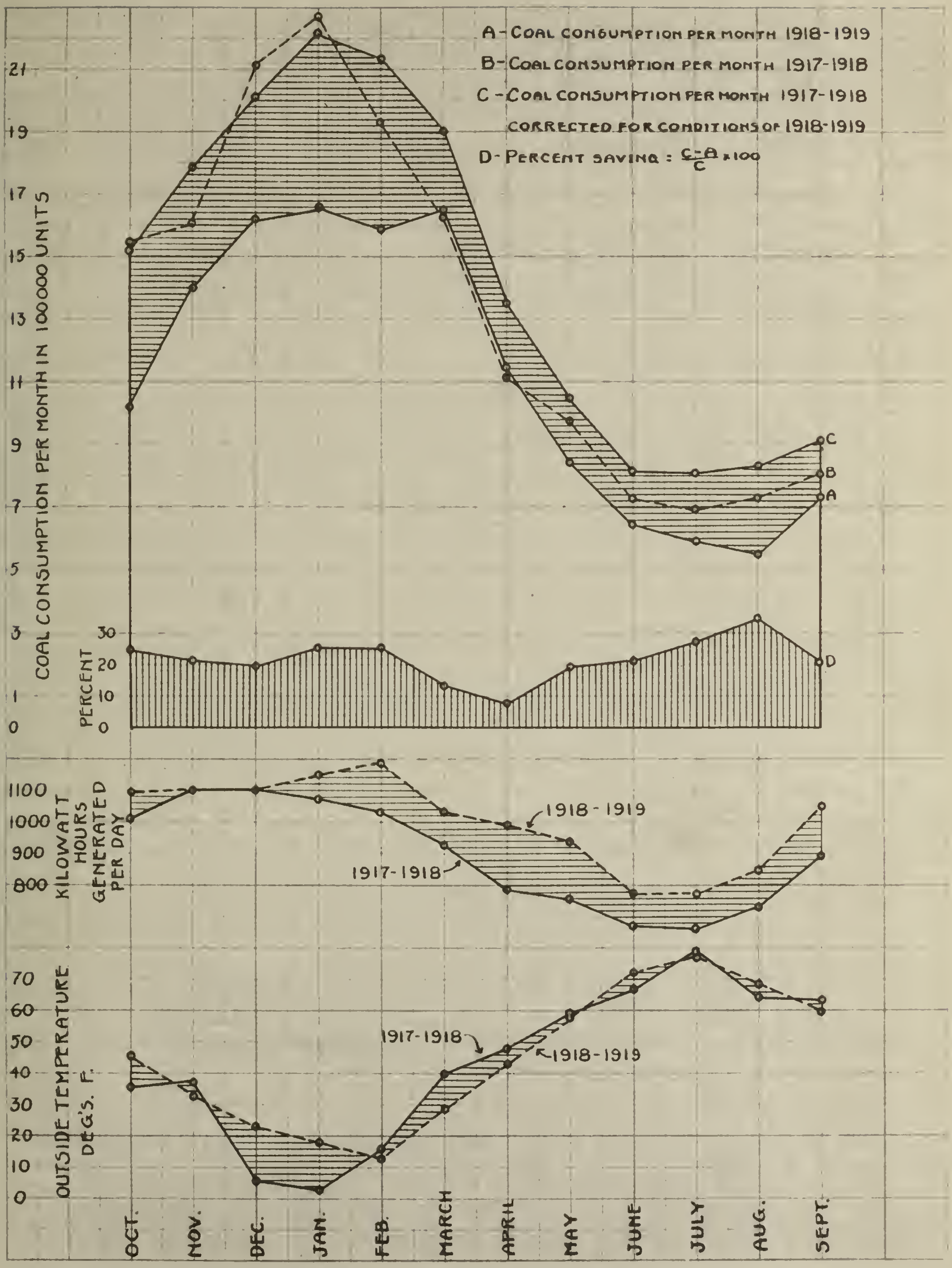
The 3 684 256 pounds of coal saved represent a value of $13,585.00. That is, if the plant had been operated in 1918-1919 in the same manner, under the same conditions, and with the same efficiency as in 1917-1918, the cost of the coal for the year 1918-1919 would have been greater than the actual amount by $13,585.00.

This saving in coal was not as great as was stated in the first report as being possible. The possible saving stated in

the first report was possible, but only on condition that all losses were corrected and the plant operated at maximum efficiency.

Obviously this requires more attention and supervision than could be given one day in each month. The results are valuable however, as being concrete evidence as to what it is possible to do in the average plant.


A- Averagehorse power rating of boilers in operation. 1917-1918
B- Average horse power rating of boilers in operation 1918-1919
C- Rated horse power reduction of boilers in service (A-B)
Average reduction 146.3 rated horse power, or 26.2 percent
A
B
C
800
700
600
500
400
300
200
100
0
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.


A - Coal consumption per month 1918-1919
B - Coal consumption per month 1917-1918
C - Coal consumption per month 1917-1918 corrected for conditions of 1918-1919
D - Percent saving : $\frac{C-A}{C} \times 100$
COAL CONSUMPTION PER MONTH IN 100000 UNITS
21
19
17
15
13
11
9
7
5
3
1
0
PERCENT
30
20
10
0
A
B
C
D
KILOWATT HOURS GENERATED PER DAY
1100
1000
900
800
1918-1919
1917-1918
OUTSIDE TEMPERATURE DEG'S. F.
70
60
50
40
30
20
10
0
1917-1918
1918-1919
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.

## TEMPERATURE CURVES

On pages 76 and 113 are curves, the coordinates of which are average monthly outside temperatures and total monthly coal consumption. The curves on page 76 were discussed in the report dated February 15, 1919.

At the time of drawing the 1918-1919 curve, data for four points only was available, and these points fell quite closely on a straight line.

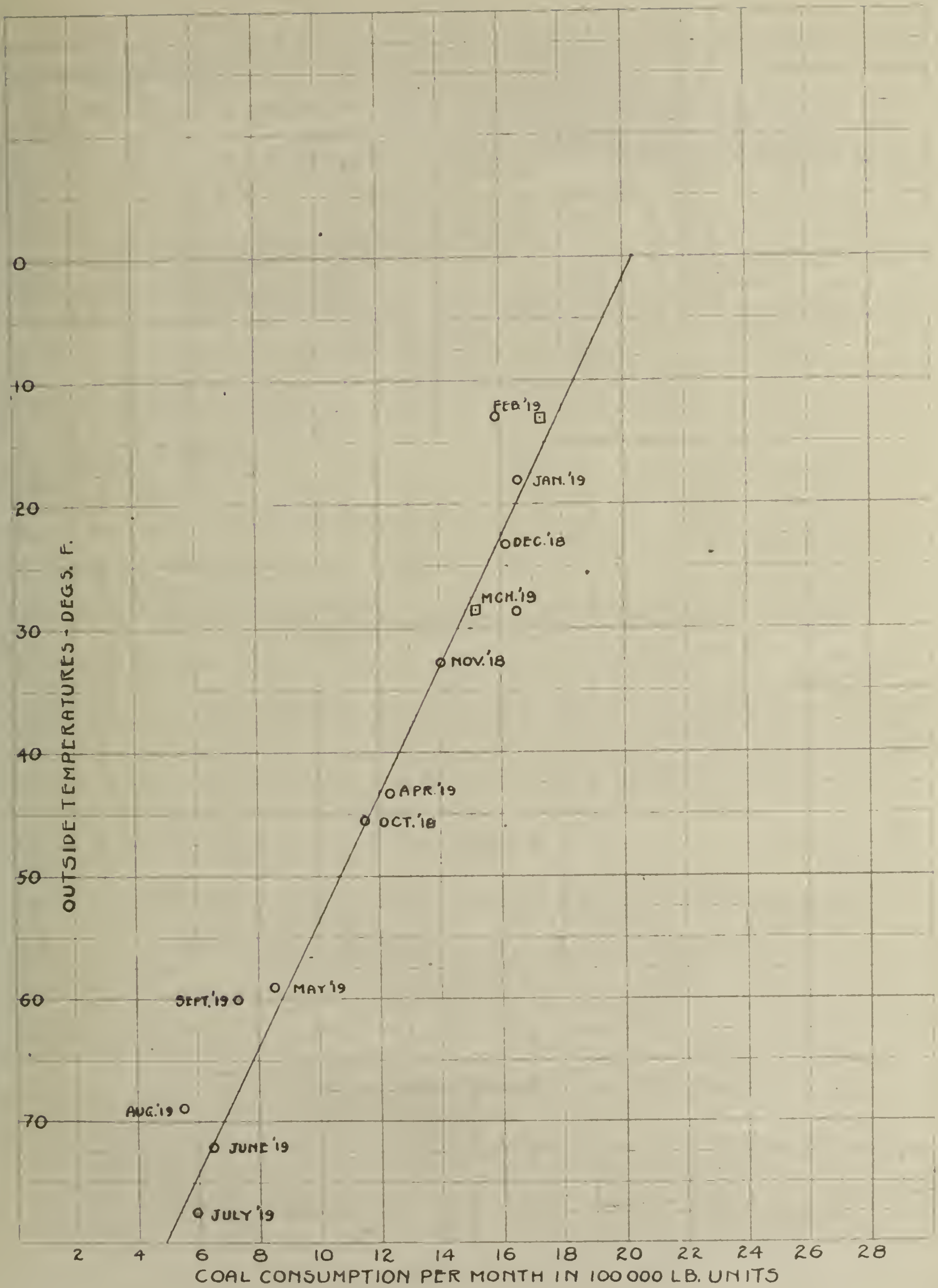
A plant such as that at Buhl is essentially a heating plant during the greater portion of the year and it should be expected that there would be some relation between the coal consumption and the outside temperature. This line showed that relation so far as data was available.

To check this relation, the line for 1918-1919 was redrawn, as shown on page 113, and extended. Points for the remaining eight months were plotted. Two of these points were corrected. Since February was a short month, a point indicated by a square, was plotted indicating what the coal consumption would have been had February been as long as the other months. March was a month of inefficient operation, and a point, also indicated by a square, was plotted indicating what the coal consumption would have been had the efficiency of operation during March been equal to the average of the other months.

Considering these two corrections, it is interesting to note that the points for all months except August and September, fall quite close to the line, and even these two do not depart radically.

It is also interesting to note that the points for the non-

heating season follow the line as well as the points for the heating season. It is possible that a graph of this character would be valuable for keeping a check on a plant which was essentially a heating plant and for making comparison between the operation of successive years, as well as of successive months.


0
10
20
30
40
50
60
70
OUTSIDE TEMPERATURES - DEGS. F.
2
4
6
8
10
12
14
16
18
20
22
24
26
28
COAL CONSUMPTION PER MONTH IN 100 000 LB. UNITS
FEB.'19
JAN.'19
DEC.'18
MCH.'19
NOV.'18
APR.'19
OCT.'18
MAY '19
SEPT.'19
AUG.'19
JUNE '19
JULY '19

## PRINCIPLES INVOLVED

Saving fuel in a power plant involves certain principles which will be briefly discussed. These come under the following heads:

1. Combustion of the fuel.
2. Utilization of the heat developed.
3. Utilization of steam within the plant.
4. Utilization of the product of the plant, without the plant.
5. Instruments.
6. Personal element.

### Combustion of the fuel

Coal should be practically completely burned on the grates and in the furnace. To do this, sufficient air should be supplied for oxidation of the combustible and thoroughly mixed with the fuel. An excess of air causes a loss of heat up the stack and a deficiency causes a loss of unburned combustible. A combustion rate should be maintained and furnace conditions should be such as to have the furnace space quite hot, as high temperature promotes ignition and makes complete combustion possible with the minimum of air.

The shape and size of the furnace and the design of the coal feed are important. The character of the coal is important as, for example, a high ash coal can reduce efficiency of combustion by preventing mixture of air and fuel, and a low fusing ash in coal causes formation of clinkers and their attendant troubles.

Moisture in the coal is a factor to be considered, although knowledge on this point is limited. It would seem that with a given coal, furnace and grates, a certain percentage of moisture

is necessary for the maximum efficiency.

Proper control of the fuel in the furnace, and of draft are necessary to obtain highest efficiency of combustion. Certain rates of combustion with given conditions result in more efficient combustion depending on design of equipment and character of coal.

Utilization of heat developed

After the fuel is burned, as much of the heat as possible must be transferred to the water and steam. Anything preventing this transmission increases the coal consumption. If air leaks into the setting, some of the heat is used to raise its temperature. Settings should be maintained air tight. Cracks and joints should be caulked and the brick work covered with a plastic coating or steel encased.

If scale exists on one side of the heating surface and soot on the other, an insulation is set up retarding the transfer of heat. If possible, water should be used containing a minimum of scale forming material in solution or suspension. An effective water softener will reduce the scale forming content. If water of this character is not available and a softener can not be had, a proper compound, depending on the analysis of the water, should be used to percipitate the scale forming material, and the boiler should be washed frequently. Tubes and flues should be blown with sufficient frequency to keep them free from soot. A mechanical soot blower is advisable but a hand lance is better than nothing. Tubes and flues should also be scraped occasionally.

Baffle design and conditions may affect the efficiency of heat transmission. Baffles should be tight to prevent leakage of gases thru them and should be so arranged to secure the maximum of

contact between the gases and heating surface. It is becoming customary with boilers of the Heine type to place the lower baffle on the third row of tubes as the furnaces become too hot at heavy loads when the lower baffle is on the lower row of tubes.

Boiler settings should be so designed to secure full advantage of the heating surface.

## Utilization of steam within the plant

The steam from the boilers, used in the plant, should be so used as to secure the greatest plant output with the least expenditure of steam; that is, the steam should be used to the best advantage depending on the individual conditions.

In the average plant, there is probably less loss in the utilization of steam within the plant than there is loss in the generation of steam, as the average power plant engineer gives more attention to the equipment using steam than to the equipment making steam.

There should be no leaks to waste steam. Steam piping should be properly designed and well covered. All radiating surfaces should be covered to conserve the heat in the steam.

Moisture should be cared for by separators, strainers and return traps.

Prime movers should be kept in condition to use the steam to the best advantage. Proper lubricating oil should be used and in the correct amounts. Valves should be properly set and moving parts properly adjusted. Sufficient exhaust steam should be used to heat the feed water to 212° F. as for each eleven degrees the feed water is raised in temperature, a saving of about one percent in coal is effected.

Where any control over the plant load is had by the operative, this load should be kept as near constant as possible. Extreme fluctuation in load makes an extreme fluctuation in boiler operation and reduces the efficiency of both production and utilization of steam. It quite often lies within the power of the operatives, to control the load to a certain extent.

The general condition of the plant and equipment should be kept to a high standard as any slovenliness or lack of system in any of the details, usually extends to the more vital details.

## Utilization of the product of the plant without the plant

The equipment without the plant should be maintained in such condition as to permit the use of the plant product to best advantage and with the least loss. For example, if the plant furnishes steam for heating, the mains and service pipes should be kept clean and free from clogging, and should be insulated and protected to prevent loss of heat.

It is of advantage in certain kinds of plants to control the use of the plant product. For example, a wasteful use of steam in steam heating, may mean a loss to the plant owner in increased coal consumption.

## Instruments

Instruments are necessary for securing information concerning operating conditions and to detect losses. Some of the principal instruments needed and not usually found in plants are:

Scales for weighing coal.

Meters for measuring feed water.

Gas analyzers for determining $CO_2$ in flue gases.

Ther mometers for determining temperatures of flue gases.

Draft gauges for determining draft pressure in various parts of boiler settings and for use in controlling air supply to furnaces.

A flue gas analyzer and a flue gas thermometer are of almost as much value if used intelligently, as if continuous boiler testing could be done.

Personal element

All the foregoing means of promoting efficiency are worthless, if the plant operatives do not have sufficient interest and knowledge to use them. A poor fireman can waste enough coal to pay the wages of a number of good firemen.

Some one person in a plant should be sufficiently informed to put into practice such things as are necessary to secure and maintain economy of operation, and should give interested supervision to all the details.

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